STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

REPORTS OF THE
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT, State Engineer

BULLETIN No. 19

SANTA ANA INVESTIGATION

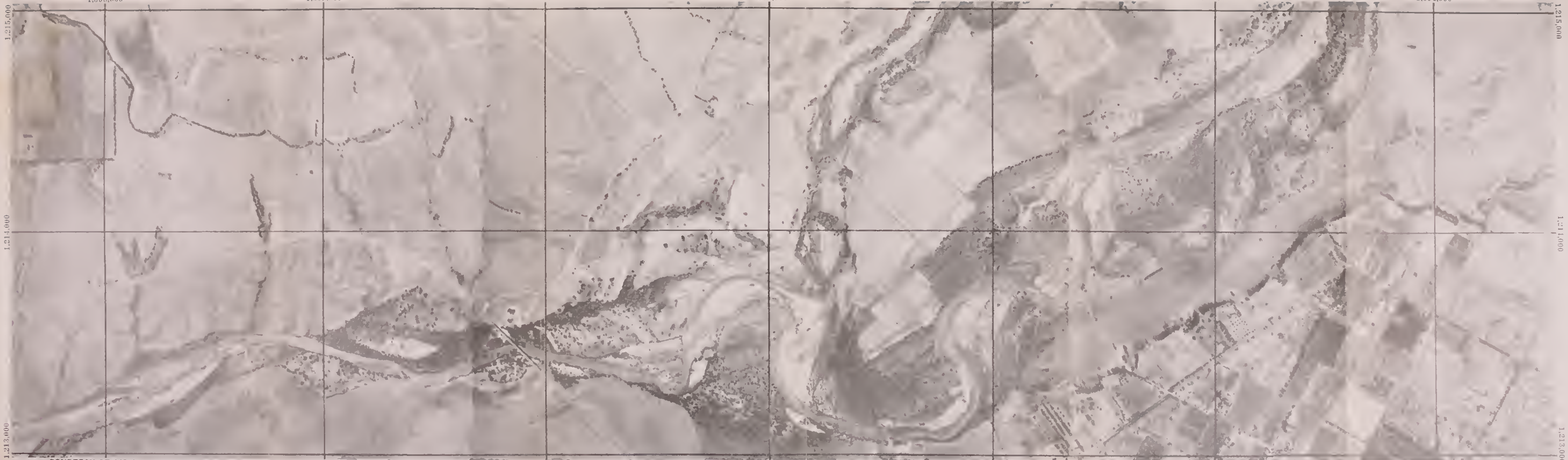
Flood Control and Conservation

A Report prepared pursuant to Acts of the Legislature, Chapter 476 of the Statutes of 1925 and Chapter 809 of the Statutes of 1927

DECEMBER 1, 1928

By WILLIAM S. POST
Hydraulic Engineer

Maps accompanying this report are bound in separate volume



COURTESY OF AIR SERVICE, U. S. ARMY
Coordinates approximate, Army Grid System in yards

SANTA ANA RIVER, WEST OF RIVERSIDE
Refer to Map 1, Sheet 2

SANTA ANA INVESTIGATION

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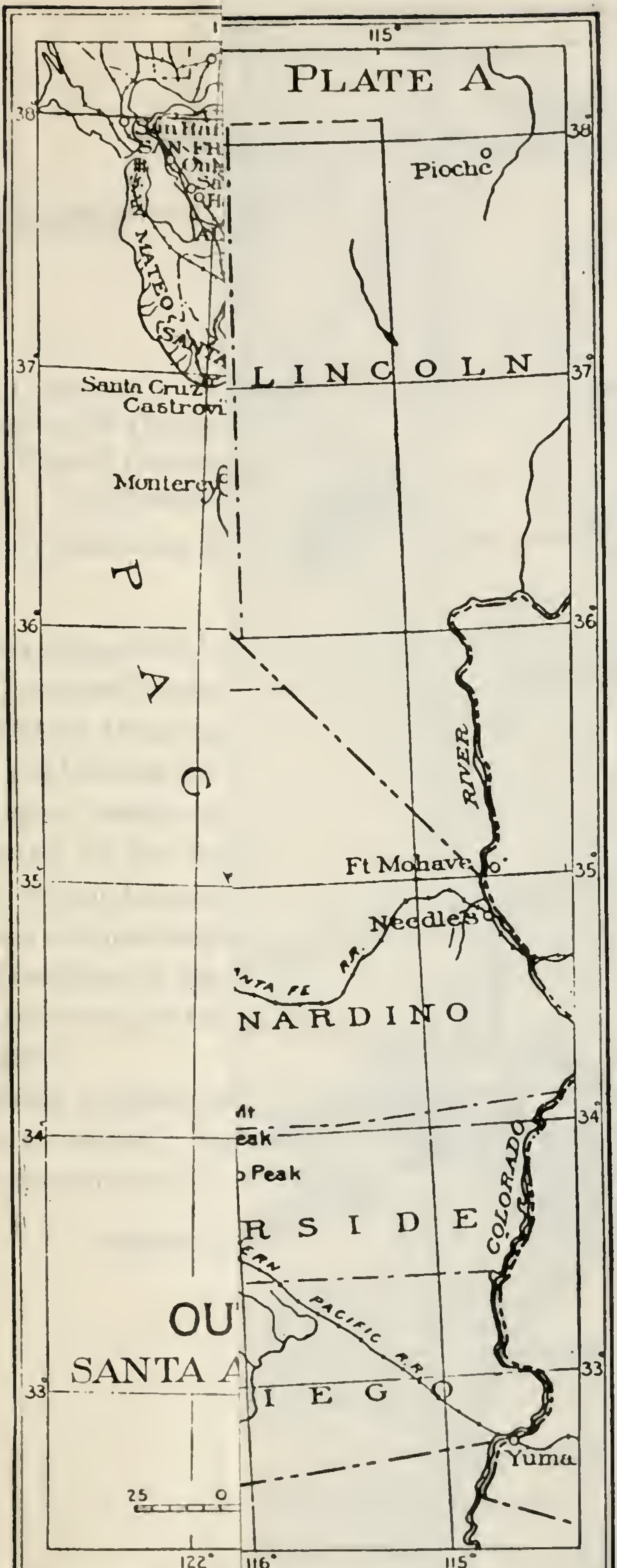
PLATE A
Pioche
SAN MATEO
SANTA
LINCOLN
Santa Cruz
Castrovi
Monterey
P
A
C
RIVER
Ft Mohave
Needles
SANTA FE R.R.
NARDINO
Peak
Peak
RSIDE
COLORADO
PACIFIC R.R.
OU
SANTA A
IEGO
Yuma
38°
37°
36°
35°
34°
33°
115°
122°
116°
115°
25
0

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PLATE A
OUTLINE MAP
SANTA ANA INVESTIGATION
Scale
25 0 25 50 75 100 miles
PACIFIC OCEAN

63685

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
SACRAMENTO

DIVISION OF ENGINEERING
AND IRRIGATION

HON. C. C. YOUNG,
Governor of California,
Capitol Building,
Sacramento, California.

Subject: Santa Ana Investigation.

SIR:

There is transmitted herewith the report entitled "Santa Ana Investigation," prepared under the direction of the Division of Engineering and Irrigation, Department of Public Works, pursuant to an act of the Legislature, Chapter 809, Statutes of 1927.

The report contains a complete study and suggested solutions for flood control on the watershed of the Santa Ana River, within the counties of San Bernardino, Riverside, Orange and Los Angeles. It embraces a detailed compilation of engineering and statistical information, a description of fifty possible unit structures and illustrative combinations of works for the consideration of public bodies in carrying out flood control.

The report indicates that flood control may be successfully achieved, and that its extent is largely dependent on the amount which public bodies eventually decide to appropriate for this purpose.

Respectfully submitted,

Edward Hyatt

State Engineer.

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ACKNOWLEDGMENTS

Acknowledgment for map information is made to the following: Bureau of Waterworks and Supply, city of Los Angeles; Southern California Gas Company; Surveyor, San Bernardino County; Surveyor, Riverside County; Surveyor, Orange County; Orange County Flood Control; Ontario-Cucamonga Fruit Exchange; Water Department of city of San Bernardino and Engineering Departments of the Santa Fe and Union Pacific railways.

Acknowledgment is made in Part III of the various water companies who have cooperated by furnishing discharge records of canals.

Acknowledgment is made to a large number of water companies who have furnished statistical information relative to service areas and use of water. These companies are listed in Table No. 46, page 219.

Acknowledgment is made of well observations furnished by Lytle Creek Conservation Association.

The preparation of the hydrographic tables has been greatly facilitated by the constant cooperation of Mr. McGlashan and Mr. Ebert of the United States Geological Survey.

It is impossible to give in detail the valuable assistance received from informal conferences throughout the course of the investigation. A general acknowledgment, however, is due to the numerous individuals whose information was placed at the disposal of the investigation.

The bulletin has been prepared in consultation with an engineering advisory committee, the members of which were:

George S. Hinckley--------(San Bernardino County)
A. L. Sonderegger-----------------(Riverside County)
J. B. Lippincott-------------1925–26 (Orange County)
Paul Bailey----------------1927–28 (Orange County)

ORGANIZATION

B. B. Meek----------------Director of Public Works
Edward Hyatt----------------State Engineer

Harold Conkling
In Supervisory Charge

William S. Post----------------*Engineer in Charge*
W. P. Rowe----------------*Special Assistant*
Chester Marliave----------------*Principal Assistant*
E. W. Roberts----------------*Office Engineer*
E. D. Stafford----------------*Topographer*
Franklin W. Bush, Jr.----------------*Hydrographer*
J. A. Case----------------*Hydrographer*
H. C. Troxell----------------*Hydrographer*

FOREWORD

Scope of work completed. The collection and summarizing of facts, bearing on flood and conservation conditions has been the prime object of this investigation. The main effort has been to arrange statistics and summaries of results in such a form that conclusions may be reached as to the method and construction of works.

The designation of what works should be built is a function of the local public bodies. The purpose of this report is to make public all possibilities which have been examined and indicate those which were technically feasible.

In the preparation of this report there were already on hand, prepared from work done in 1925-26, topographic maps and detailed estimates of cost on 14 reservoir sites, an analysis of the hydrography of the Santa Ana River and its tributaries, preliminary estimates of reservoir performance, records of dam site exploration by core drilling on two sites, well measurements and underground water studies, a survey of irrigated lands and a geologic report. The "Report of Santa Ana Cooperative Investigations" for 1925-26, dated April 2, 1927, prepared by the then State Engineer, with the approval of a consulting engineering committee will be found published in full in the succeeding section, page 9.

In the fall of 1927, a round of well measurements was made throughout the Santa Ana watershed; stream gaging stations were installed on 58 streams, which have not been hitherto measured, and records of diversion were collected from water organizations, as far as necessary to complete the statistics of inflow and outgo from various basins. The most important of the new gaging stations are on the Santa Ana at Colton, the Santa Ana at Pedley Bridge, and the stations measuring the escape of water into the ocean.

As the season, 1927-28, proved to be one of small run-off, it became increasingly desirable to include the season of 1926-27, which was above normal. There is presented in Part II an intensive study of these two seasons, in which all minor streams are included. This study is intended to be the guide form for future hydrographic observations and is thought to be more complete than any preceding type of analysis.

In the fall of 1927, cooperation was undertaken with the U. S. Department of Agriculture in charge of H. F. Blaney, to determine the penetration of rainfall into the ground water on the valley floor. This determination is of vital importance in the accurate analysis of water conditions. Heretofore it has been an uncertain element of all studies.

A complete survey of flood heights of 1927 on all major and minor streams has been made and maximum discharges calculated.

On account of the lack of a modern base map upon which to publish results, there has been prepared a base map on a scale of one mile to one inch. There have also been prepared seven maps of the Santa Ana River and Lytle creek from various authentic surveys and from original surveys by this investigation.

Surveys of five reservoir sites were also made in 1928, and test borings on two of these sites. On the Prado reservoir site, an intensive geological study and test drillings have been prosecuted in cooperation with Orange County Flood Control.

LEGISLATIVE ACTS

The initial act providing for the Santa Ana investigation was passed by the Legislature of 1925, as follows:

CHAPTER 476

An act to provide for the survey of and works in and upon the Santa Ana river watershed and basin for flood control; and making an appropriation therefor.

(I object to the item of fifty thousand dollars in section 1 and reduce the amount to twenty-five thousand dollars. With this reduction I approve the bill. Dated: May 23, 1925. Friend Wm. Richardson, Governor.)

The people of the State of California do enact as follows:

SECTION 1. The sum of fifty thousand dollars is hereby appropriated out of any money in the state treasury, not otherwise appropriated, to be expended under the direction of the division of engineering and irrigation, state department of public works, for the purpose of making a survey of the Santa Ana river watershed and basin and for the construction of works for the control of floods of the Santa Ana river and its tributaries; *provided, however,* that the sum herein appropriated shall not be available until an equal amount shall have been appropriated for the same purpose by the counties of San Bernardino, Riverside and Orange.

The Legislature of 1927, under Senate Bill No. 888 presented by Hon. Ralph Swing appropriated the sum of $40,000, provided an equal amount be appropriated by the counties for a continuance of this work. By action of the counties, one-half of this sum, or $40,000 in all, became available in October, 1927. After July, 1928, the remainder was made available. The act is as follows:

CHAPTER 809

An act to provide for a survey of and works on the Santa Ana river watershed and basin for flood control and making an appropriation therefor.

(I object to the item of fifty thousand dollars in section 1 of Senate Bill No. 888, and reduce the amount to forty thousand dollars. With this reduction, I approve the bill. Dated: May 28, 1927. C. C Young, Governor.)

(Approved by the Governor, May 28, 1927)

The people of the State of California do enact as follows:

SECTION 1. The sum of fifty thousand dollars is hereby appropriated out of any money in the state treasury, not otherwise appropriated, to be expended under the direction of the division of engineering and irrigation, department of public works, for the purpose of making an investigation and a survey of the Santa Ana river watershed and basin to determine the method of and the construction of works for controlling the floods of said Santa Ana river and its tributaries. Said investigation and survey shall be completed and a report thereof made to the governor prior to the first day of December, 1928; *provided, however,* that such sum shall be available when there is available or shall hereafter be made available by any political subdivision, or subdivisions of the State of California or by the federal government, or by other interested party, or parties an equal amount for such purpose.

FINANCIAL STATEMENT

Appropriation, 1925–26.

Under chapter 476, Statutes of 1925, the state appropriated $25,000; the counties appropriated $25,000 ---- $50,000

Segregation of Appropriation, 1927-28;

(State of California $40,000; counties $40,000.)

Equipment	$2,000
Office	12,000
Well measurement	5,000
Hydrography	14,000
Surveys	4,000
Reservoirs, drillings and geology	10,000
Publication	10,000
U. S. Department of Agriculture	12,000
U. S. Geological Survey	11,000
	$80,000

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Water Spreading as a Measure of Flood Control, Willis S. Jones, South. Calif. Section, Am. Soc. C. E., Bulletin, Volume 1, No. 4, 1919.

Colorado River Project.

The proposed Los Angeles-Colorado River Aqueduct Project, E. A. Bayley and H. A. Van Norman, presented at meeting Am. Soc. C. E. at Denver, July 14, 1927.

Colorado River-Los Angeles Aqueduct Project, H. A. Van Norman and E. A. Bayley, Engr. News-Record, May 31, 1928.

Geology.

U. S. Geological Survey, Bulletin 768, Geology and Oil Resources of the Puente Hills Region, Southern California, Walter A. English, 1926.

PROGRESS REPORT FOR 1925-26

On April 2, 1927, a report* was made by the former State Engineer on work done in 1925–26, as follows:

To the Governor of California and the State Legislature, Session of 1927.

HONORABLE SIRS:

The Water Problems of San Bernardino, Riverside and Orange Counties.

The main source of water for these three counties is the Santa Ana River and its tributaries draining 1485 square miles above the lower canyon of the river which is near the eastern boundary of Orange County. The grand total water crop from this area for the last thirty years has been estimated at over three hundred thousand acre-feet per annum. This water is discharged largely in the form of torrential floods during the winter, followed by extremely low stages in the summer when it is most required. In Orange County 80 per cent of the total supply is now obtained from wells and probably over 50 per cent in San Bernardino and Riverside counties. In Orange County these large drafts on the ground water supply is causing its serious depletion. The same is true in large areas in San Bernardino County. In all three counties there is an excess of land not now served with water, which under its present condition has little value but if properly supplied with water would become exceedingly productive and valuable. The winter floods frequently occur in great volume rushing to the sea and causing great damage in their course. In Los Angeles County these flood damages in 1914 and 1916 were estimated at ten million dollars. The flood in February, 1927, destroyed bridges at a loss of approximately four hundred thousand dollars in Riverside County. In Orange County the flood of 1916 is estimated to have done one million dollars in damage. The amount of damage in San Bernardino County while large, has not been estimated for 1927.

Plan of Study.

The three counties of Orange, Riverside and San Bernardino realizing the importance of an adequate water supply during periods of necessity, and the avoidance of flood damage, requested the State of California to assist them in finding some remedy. This resulted in the passing of a state appropriation of $25,000 to be expended during the fiscal period 1925-1927 as contained in chapter 476 of the Statutes of 1925. This instructed the State Engineer's office to carry out a water supply study in cooperation with the three counties, provided the three counties contributed an equal sum to this work. This county cooperation was obtained. Each county also appointed an engineer to represent it in consultation with the State Engineer. In addition to this the three counties are cooperating in the actual work of conserving flood waters by spreading them on the debris cones where the streams leave their mountain canyons. The water companies which are practically all

* Report on Santa Ana cooperative investigations pursuant to Chapter 476 of the Statutes of 1925, by State Engineer and Engineering Consulting Committee appointed by Orange, Riverside and San Bernardino counties. April 2, 1927.

public institutions have been expending funds in investigation for the conservation of the winter flows by spreading in the higher portion of the mountain basins.

The Proposed Remedy.

The remedy for the problem of flood prevention and conservation as contemplated consists in the storage of flood waters in the mountains for purposes of regulation and conservation. It is also proposed to store flood waters in the lower portion of the drainage basin before they reach the coastal plain and to regulate the winter flow for summer use. By the regulation of these floods it will be possible to handle them in such a way that much greater quantities of water can be put under ground by spreading and absorption so as to sustain the ground water levels.

Work Accomplished.

The work accomplished during the biennium under the 1925 appropriation consists of an investigation of the available water supply and of the flood flows in all the tributaries of the Santa Ana except the San Jacinto. Reconnaisance of over 40 miles of stream channel was made for reservoir sites with which their floods might be controlled. Field surveys were made of the sites found, the reservoir capacities determined, cost estimates made for several heights of dam at each site, and the degree of control of floods determined for several reservoir capacities. In all 19 dam sites and 13 separate reservoir sites were so investigated. The foundations of two of the dam sites were explored with the diamond drill. In addition, an underground water contour map was made of the Santa Ana Basin and much data collected on the subsurface supply and the use of water.

Work Remaining to be Done.

While the investigations provided for in the act referred to above, have been carried on diligently and continuously for the last two years the problem has been found to be so complex and involves such great values that a conclusion as to the best method of procedure and remedy cannot yet be stated. Some of the dam sites surveyed have not been explored for bedrock. Others have been surveyed so recently that time has not been available for the study of plans and estimates. It is particularly important that the ground water supplies should be more thoroughly investigated as a large portion of the water must always be derived from this source. When the physical data is complete some reasonable plan should be outlined for the improvement of the entire basin as a unit if possible.

Probably the largest undeveloped supply in Southern California is the Mojave River in San Bernardino County. Very little is known of this stream except that its flood discharge is very great and its low water flow exceedingly small. Reservoir sites exist and the underlying lands are desert. We recommend that this water supply study should be extended to the basin of the Mojave River.

Estimated Cost of Work.

It is proposed that the three counties should continue their studies and experiments as to the effectiveness of putting flood waters under ground by spreading operations, and that these counties should bear this portion of the expense. Partly in consideration of this, we advise that the state continue their general hydrographic studies of surface and ground waters in these three counties including the Mojave River. The estimated cost of continuing this state work for the coming two years is $75,000.

Respectfully submitted.

PAUL BAILEY,
State Engineer.

Approved:

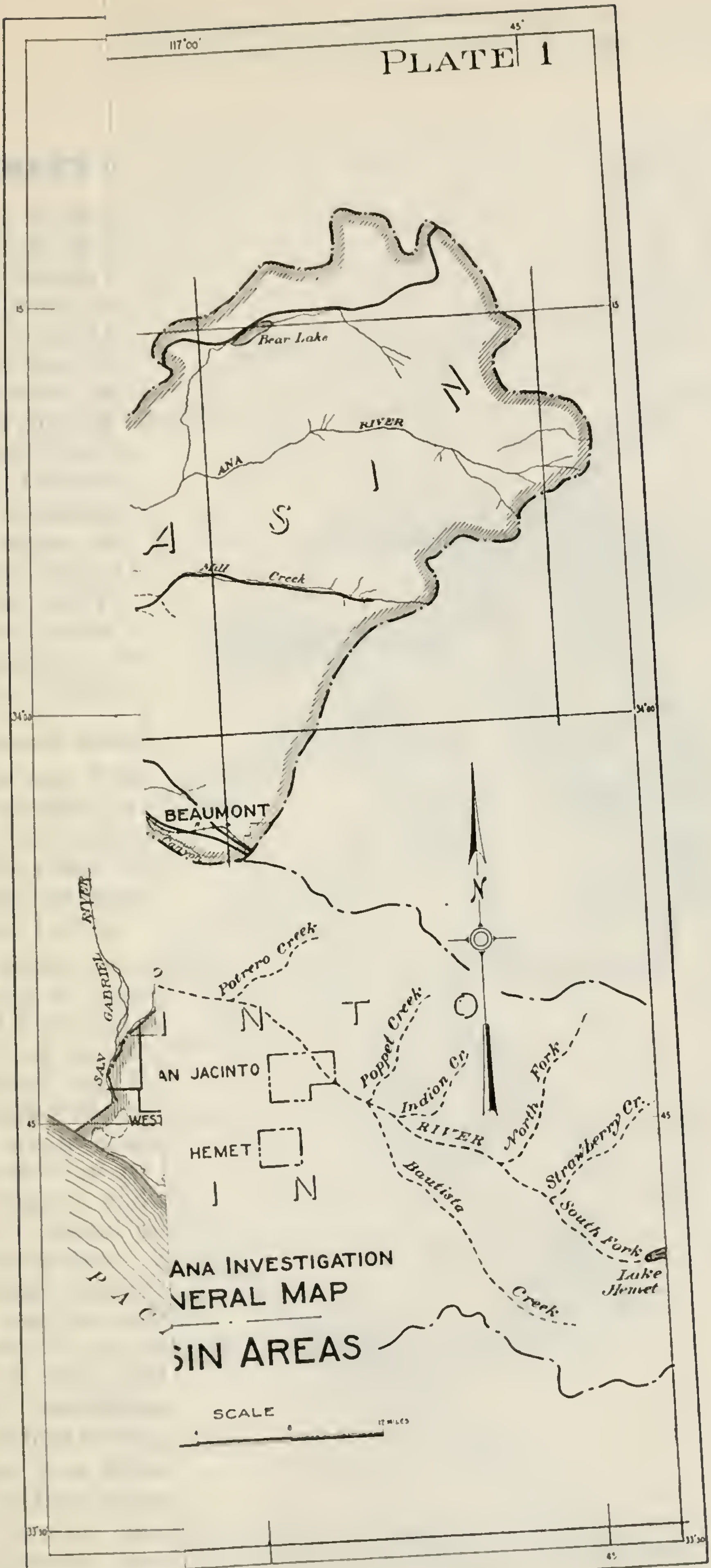
CONSULTING ENGINEERING COMMITTEE.

J. B. LIPPINCOTT,
Representative from Orange County.

A. L. SONDEREGGER,
Representative from Riverside County.

GEO. S. HINCKLEY,
Representative from San Bernardino County.

PLATE 1



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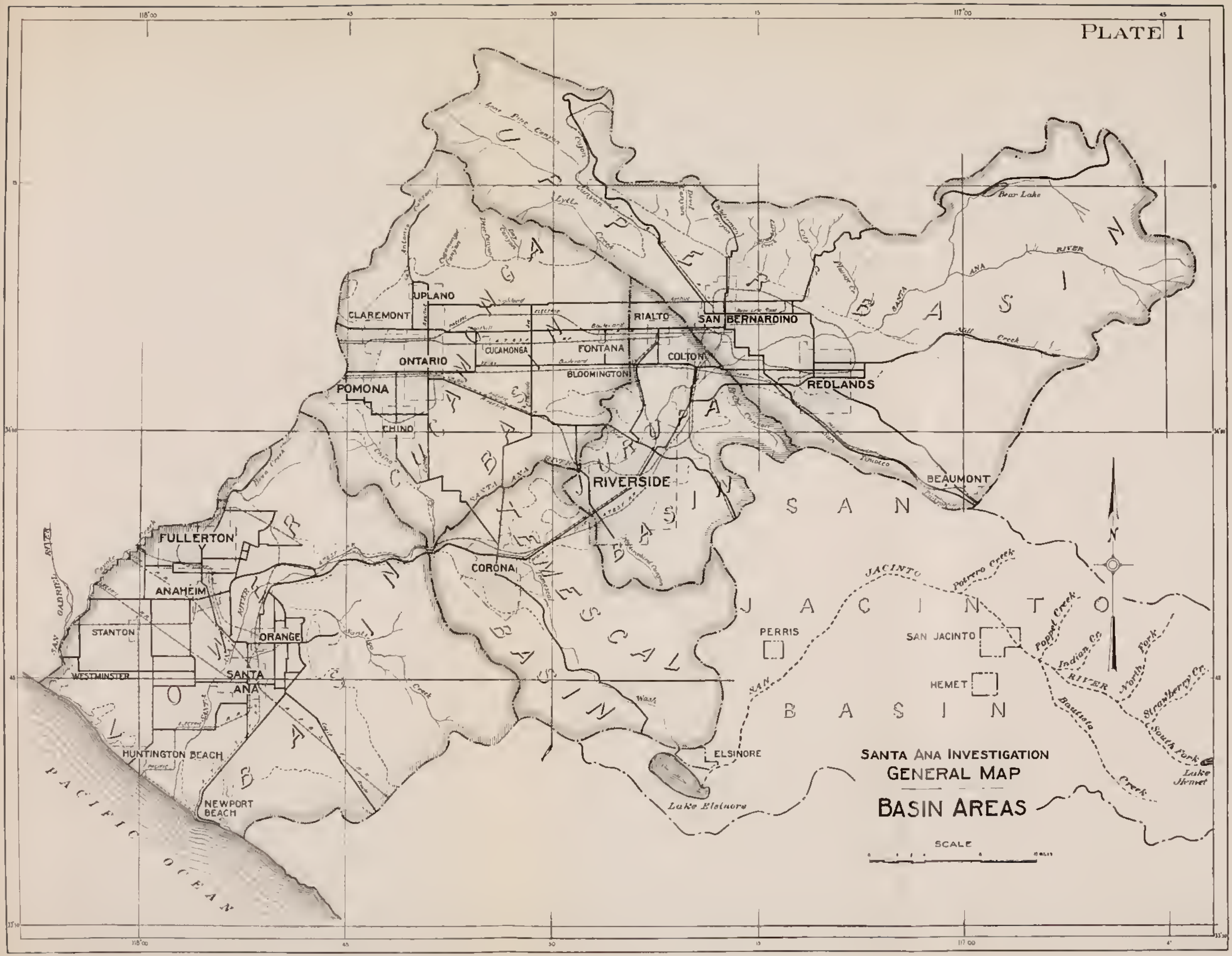

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SUMMARY OF REPORT ON SANTA ANA INVESTIGATION

In the following summary of the results of Santa Ana investigation the obscure underground situation is briefly outlined, the estimated present wastes of water both surface flow into the ocean and from seeped lands are tabulated, the most obvious flood control works are described and their estimated effect both on floods and on conservation of water are given. No attempt has been made to describe minor works or alternative works, the effort being to place the vital information in as compact form as possible. No recommendations are made, but from the estimated effect and the cost it is believed that a basis is laid for a program by the interests involved.

This summary introduces the more elaborate and detailed portion of the report which covers all the various possibilities in Santa Ana Basin in order to facilitate consideration of any program. The estimates on water in the report proper and used in this summary were submitted while in preparation to Mr. Hinckley, Mr. Sonderegger and Mr. Bailey, a board of advisory engineers representing the three counties of Santa Ana Basin.

The Physical Situation.

Santa Ana Valley consists of a series of basins, mesas and hills. The basins are filled with detritus brought down from the precipitous mountains by the sudden violent floods of the region. They are separated one from the other by hills and mountain ranges or by underground barriers such as Bunker Hill Dike crossing the valley between San Bernardino and Colton.

The basins are as shown on the accompanying Plate 1. Upper Basin is defined by Bunker Hill Dike. It could be divided into East Upper, Lytle Creek and Yucaipa-Beaumont subbasins. Jurupa Basin might be divided into Colton and Riverside mesa. Cucamonga Basin could be divided into Upper and Chino and even these further subdivided. These subdivisions are suggested by changes in character of valley fill which create changes in water conditions. Temescal Basin is not of great effect in its regulation of or contribution to the underground water supply, and no notation is made of possible subdivisions. Lower Basin or coastal plain has an upper percolating area and a lower nonpercolating area. The most definite division between basins is the mountain range separating the coastal plain from the rest. San Jacinto Basin was not studied in detail. Lake Elsinore detains its waters so that they do not add to the flood hazard of Santa Ana River. Small reservoir sites exist in the headwaters, but were not studied for flood control possibilities. Hazard to property in and near the town of San Jacinto exists, which a simple system of dikes will correct.

Santa Ana River (plus Mill Creek) discharges 43 per cent of the total surface mountain run-off. Even with this concentration, water flows from the mountains to the ocean only during or a short time after a heavy rain. In all the remainder of the time the stream is absorbed in the porous detritus across which it flows. Water percolates to the underground water plane and travels slowly in the direction of the flow

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Santa Ana River (plus Mill Creek) discharges 43 per cent of the total surface mountain run-off. Even with this concentration, water flows from the mountains to the ocean only during or a short time after a heavy rain. In all the remainder of the time the stream is absorbed in the porous detritus across which it flows. Water percolates to the underground water plane and travels slowly in the direction of the flow of the surface stream until a barrier either underground or surface pushes it to the surface as rising water. Below the barrier another basin is crossed, percolation takes place and again the underflow becomes rising water at the next barrier. On Santa Ana River the first percolating area in Upper Basin begins at the mouth of the canyon, and extends to a point seven miles below the mountains, where Bunker Hill Dike begins to make its presence felt and water is forced to the surface for a distance of six miles. Then comes another percolating area seven miles long in Jurupa Basin. Then above Riverside water is again brought to the surface and this increases in amount for 18 miles until entrance to the lower Santa Ana Canyon, remains fairly constant through the upper third of the canyon, and below that point commences to show a decrease. For 17 miles in the coastal plain to a point near the city of Santa Ana is the third percolating area. Below that to the ocean must formerly have been an area of rising water but the present diminished pressures no longer cause rising water. However, the surface water plane is perched on impervious strata thus preventing percolation. The percolating areas in the Upper Basin, in Colton subbasin and in the coastal plain are the important ones.

These basins of vast unconsolidated gravel fills constitute reservoirs from which most of the water supplies of the region are drawn by means of pumps. They are supplied by percolation from streams that cross them, by percolation from rain on the valley floor itself and by percolation from irrigation. They absorb the heavy flows and rains of the wet years and hold them for the dry years. The characteristic of the climate is the large annual and cyclic variation in precipitation and run-off, and this is ironed out and equated by these underground reservoirs. Without them the economic development of the region would have been impossible. This may be inferred from the fact that 90 per cent of the water supplies are derived from them either by pumps or by gravity diversions of rising water which is due to and regulated by them, and from the fact that only 10 per cent of the mountain run-off escapes into the ocean at present because of their absorptive and retentive qualities. Above present water levels, it is estimated that 1,500,000 acre-feet of water have been stored in them at the highest level of historical times and through the action of nature alone. A conservation program will adopt nature's method of storage and seek to make it more efficient.

Water is supplied to the reservoirs by percolation from rain and stream flow. Nature's method of disposing of the supply was by outflow underground or as rising water at the lower end of each basin, or by evaporation from moist areas. Underground outflow and rising water from an upper basin are supplies to the next lower basin. Finally in the coastal plain the inflow was disposed of by waste into the ocean either underground or as rising water and by evaporation from the very large area of surcharged land. The outflow from each basin was fairly constant but the supply presumably has always had wide annual variation; hence the water level in the parts of the basins distant from the natural outlets varied in the past with wet and dry years just as it now does.

A lowered water plane decreases the outflow and wasteful evaporation. When irrigation by pumping begins in any basin a new draft begins in addition to the natural drafts above noted, and the water plane must therefore lower. This is a natural and necessary outcome. If the natural outflow decreases by an amount equal to the new irrigation draft, there is no overdraft on that particular basin, but the supplies to the next lower basin are decreased. If the irrigation draft goes on to a point where it exceeds the amount of reduction in outflow and waste by evaporation, the basin is overdrawn. The water plane may however lower so greatly that pumping becomes very expensive before the outflow ceases or is even seriously diminished, and in most cases it is a practical impossibility to stop all flow of this nature from one basin to the other. In such case the overdraft exists without entire stoppage of outflow. Decrease of outflow from an upper basin causes a decreased supply to the next lower basin. Hence the tendency is for pumping in an upper basin to be reflected in the lowest basin.

The Water Situation.

Supply. The total supply which is or may be made usable is estimated to have averaged 446,000 acre-feet for the last 34 years. This is composed of 123,000 acre-feet of rainfall on the valley floor not immediately evaporated or consumed by vegetation but which in main part percolates to the water plane or in small part wastes into the ocean; and of the mountain and hill run-off estimated to total 323,000 acre-feet inclusive of both surface and subsurface flows, of which the main part percolates into the gravels of the streams or is diverted directly by gravity ditches. The amount of the 446,000 acre-feet reaching the ocean is estimated at 33,000 acre-feet via Santa Ana River. This waste occurs during floods and is the estimated average for the last 34 years. In addition there is a continuous waste into the ocean through surface drains and an assumed underflow around the fringe of the coastal plain estimated to be 20,000 acre-feet, and also the storm waste from the hills of the coastal plain which does not drain into Santa Ana River is estimated to have averaged 2000 acre-feet for the past 34 years. This leaves 391,000 acre-feet in the valley to support beneficial use and natural losses.

In addition to the above wastes there are other wastes which may be recoverable and all are listed in the following tabulation:

Estimated Waste Which may be Recoverable

		Acre-feet
(1) Storm water into ocean through Santa Ana River Channel from mountains and rain on valley floor, average for 34 years prior to 1928		33,000
(2) Miscellaneous wastes into ocean along the fringe of coastal plain consisting of underflow, discharge from hills and discharge from drainage ditches		22,000
(3) Evaporation from moist lands		
(a) In Upper Basin above Bunker Hill Dike	20,000	
(b) Coastal plain marshes near Bolsa Chica	10,000	30,000
(4) Evaporation in and along river bed between Colton and Yorba (above Santa Ana)		15,000
		100,000

NOTE.—Detail work is under way to more accurately determine quantities under items (2), (3) and (4).

The following tabulation shows the change in water plane between 1903 when a general survey was made and 1927 when the last survey was made.

	Average change in ground water level 1903-1927, feet
Upper Basin	
East (artesian area slightly decreased)	+26
Lytle Creek	—100
Cucamonga Basin	
Upper	—45
Chino (artesian area disappeared)	0
Jurupa Basin	
Colton	—8
*Riverside Mesa	Unknown
**Temescal*	Unknown
Coastal Plain (artesian area greatly reduced)	—33

* Water supplies for Riverside mesa and in part for Temescal Basin are imported from other basins and change in water plane is unknown and unimportant although deep percolation from irrigation should have raised the water plane in those areas.

The changes in water plane given in the foregoing table have taken place during a period when the water supplies were greater than average and when irrigation development especially in Cucamonga Basin and coastal plain was less than present. Taken at face value they would indicate a very large overdraft on these basins but this large recession is believed mostly due to readjustment and decrease of waste in accordance with natural processes noted in a preceding paragraph. They indicate that there is no shortage in East Upper Basin and that shortages do exist in Lytle Creek, Upper Cucamonga, Colton and coastal plain.

Development.

Present area irrigated or having a municipal supply is 368,000 acres. In 1912 it was 215,000 acres, the average increase since then having been about 10,000 acres per year. There are 226,000 acres now unirrigated which, at the estimated increased consumption over native vegetation on the dry soils, will require 226,000 acre-feet additional to the present utilization. It is estimated that the average crop consumes 1.0 acre-foot more water than native vegetation on the dry soils. On wet areas it is believed that after drainage, even if the land is cropped, present consumption will decrease.

The Flood Situation.

Water comes in sudden violent flushes from the mountains and joins with the even more flashy discharges from the hills and valley. As distance from the mountains increases the flood peaks from tributaries and valley are less likely to synchronize with those from the mountains. The short time peak from the mountains may be two or three times the average for the day but the peak in Santa Ana channel in the coastal plain is believed to be not more than 30 per cent in excess of the average for the day.

Most interest lies in Santa Ana River (plus Mill Creek). In the first six miles flowing across the cone no danger to life or great damage to property is probable. From above San Bernardino to below Colton riparian property is subject to overflow. Below Colton to the lower end of Lower Santa Ana Canyon the channel is well defined and probable damage is mostly to bridges. In the coastal plain the town of Anaheim is in great jeopardy as are also considerable bodies of land and hazard to life is large.

On the tributaries above Cucamonga plain, damage to property only is probable. Lytle Creek flowing through San Bernardino and Colton gives jeopardy to life and also large property hazard. Property is endangered in less degree by the smaller tributaries to the east of Lytle Creek. On the east side of the river the important streams are San Timoteo, Temescal and Santiago creeks. Property hazard exists on all three and is especially large for Santiago Creek which flows through the city of Santa Ana.

Methods of Flood Control.

Flood control is commonly accomplished by flood control reservoirs to smooth out peaks or channel improvement or a combination of the two. In southern California natural percolation in the stream beds reduces floods. In Santa Ana Basin and also to an extent in other basins increase of percolation by artificial spreading has been accomplished. Although such works heretofore installed have not primarily been for the purpose of flood control, yet if operated during flood peaks they will reduce such peaks. This is the exact antithesis of channel improvement which hurries the water through the channel. Spreading slows its velocity so that it can percolate and thus decreases the flood.

Likewise by merely slowing up the water through flood control reservoirs additional amounts will be caused to percolate into the stream bed. Therefore flood control accomplished in that way will also accomplish conservation. Flood control accomplished by channel improvement only may bring an increase in waste of water. The situation regarding water supply makes it desirable to choose methods and location of structures which effect the greatest conservation and make the salvaged water available where most needed. It was for this reason that the investigation dealt so largely with water supply, and so much space has been devoted to water supply in this summary.

The tributaries west of Lytle Creek except in the most violent floods sink into the gravels before they reach the river. Consequently, channels are not maintained across the lower Cucamonga Basin. Property damage results when the extraordinary flood carves new channels and forces its way to the river. The method of control will be to increase percolation by proper spreading works, located where property improvements are small, thus dissipating the water in the same way that nature now does in the gravel cones, supplemented by channels where necessary to carry the excess to the river. Cost of reservoirs in these tributaries precludes recourse to them. Ultimate extent of spreading works will be dictated by experience. The tributaries east of Lytle Creek have the same characteristics as those west but there is less waste land, property improvements are much greater, and distance to the river is less. Spreading works here also are indicated, but these may have to be supplemented by channels to the river.

The larger tributaries present a different problem. The discharge of Lytle Creek is large, and property through which it flows has high value. Hazard to life exists in Colton. A reservoir of 5000 acre-feet capacity may be built in Turk Basin which will reduce floods about 2500 second-feet, and enable them to be spread in the channel and on the east side to an extent or diverted to the Rialto area, or they may go to the river direct through an improved channel. Both San Timoteo Creek and Temescal Creek are susceptible of reservoir control but possible property damage is not large and channel improvement would almost eliminate it. On Santiago Creek a reservoir of 24,000 acre-feet capacity at Upper or Lower sites would reduce the capital flood to 2300 second-feet through the city which capacity could be provided by almost negligible channel improvement. All control on tributaries by spreading or properly designed flood control reservoirs contribute to reduction of flood hazard on the river itself. The greatest possible damage is from the river.

From the physical standpoint the most obvious combination on the river is (1) reservoirs in Santa Ana Canyon and Mill Creek in the mountains but near the debouchure into the valley, (2) superspreading on the cone, (3) channel improvement and protection works in the migratory section from above San Bernardino to a point opposite Colton, (4) a reservoir in lower Santa Ana Canyon and (5) channel improvement from the canyon to the ocean. Such a combination would give regulation above each dangerous reach of the river and above each spreading ground, and an improved and confined channel below. It would also function well from the standpoint of conservation because of the large areas of irrigated land below each reservoir. The separate units which comprise the foregoing combination in Santa Ana Valley should receive careful consideration of cost as compared to benefit before adoption.

In what follows the estimated accomplishment of the separate units of the foregoing are set out, but before going into the matter the basis of the estimates as to floods should be noted. The largest flood of record on the Santa Ana gave at Mentone near the point where Santa Ana River debouches from the mountains an average day's discharge of 13,000 second-feet, and a peak estimated at 29,000 second-feet on January 27, 1916. It is to be expected that a larger flood will occur, and for the purpose of the report a flood of twice the peak and twice the total volume was assumed and called the capital flood. This is a flood far in excess of anything known on the Santa Ana. It may occur next year or not for a hundred years.

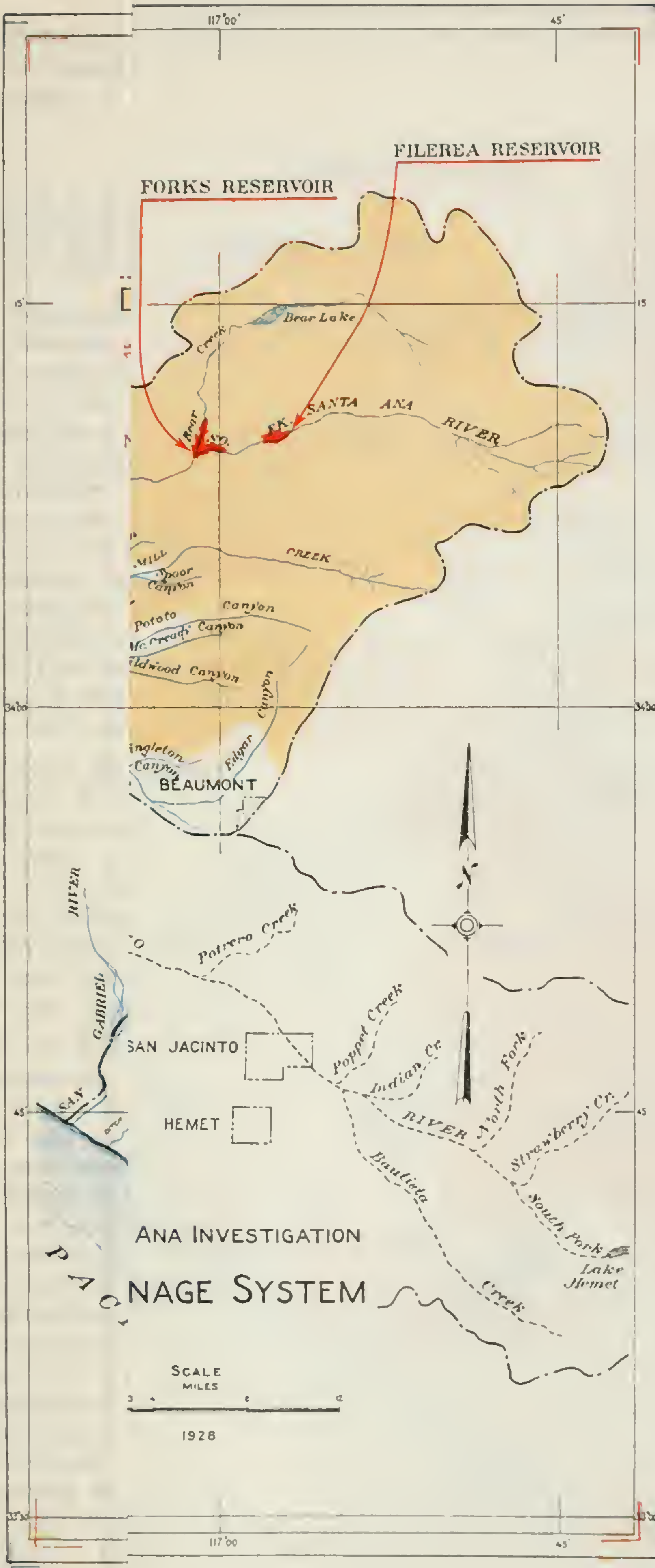
The following tabulation shows the estimated discharges for the 1916 flood and the capital flood at various points.

Estimated Discharges of Santa Ana River in Second-Feet

	1916 Flood Average day's discharge	*Estimated peak discharge*	*Estimated capital flood average day's discharge*
At San Bernardino	27,000	40,000	54,000
Below junction with Lytle Creek	31,000	43,000	62,000
Below Prado	38,000	43,000	76,000
At Santa Ana City	44,000	50,000	88,000

Spreading works in Santa Ana Cone. Only spreading of Santa Ana River is here discussed. Similar works can be built on Mill Creek. The spreading works are ultimately assumed to consist of a permanent dam at mouth of canyon, a tunnel through the north abutment, and various walls and spreading devices on the north side of the river, the whole to occupy about 5000 acres. The tunnel capacity is taken at 5000 second-feet. It is probable that in the unfavorable conditions of a capital flood, full efficiency can not be maintained and it is assumed that the capacity of the works will then be reduced to 3000 second-feet.

In the following table are shown the number of days during the 32-year period begining with 1896–97 in which the average day's flow



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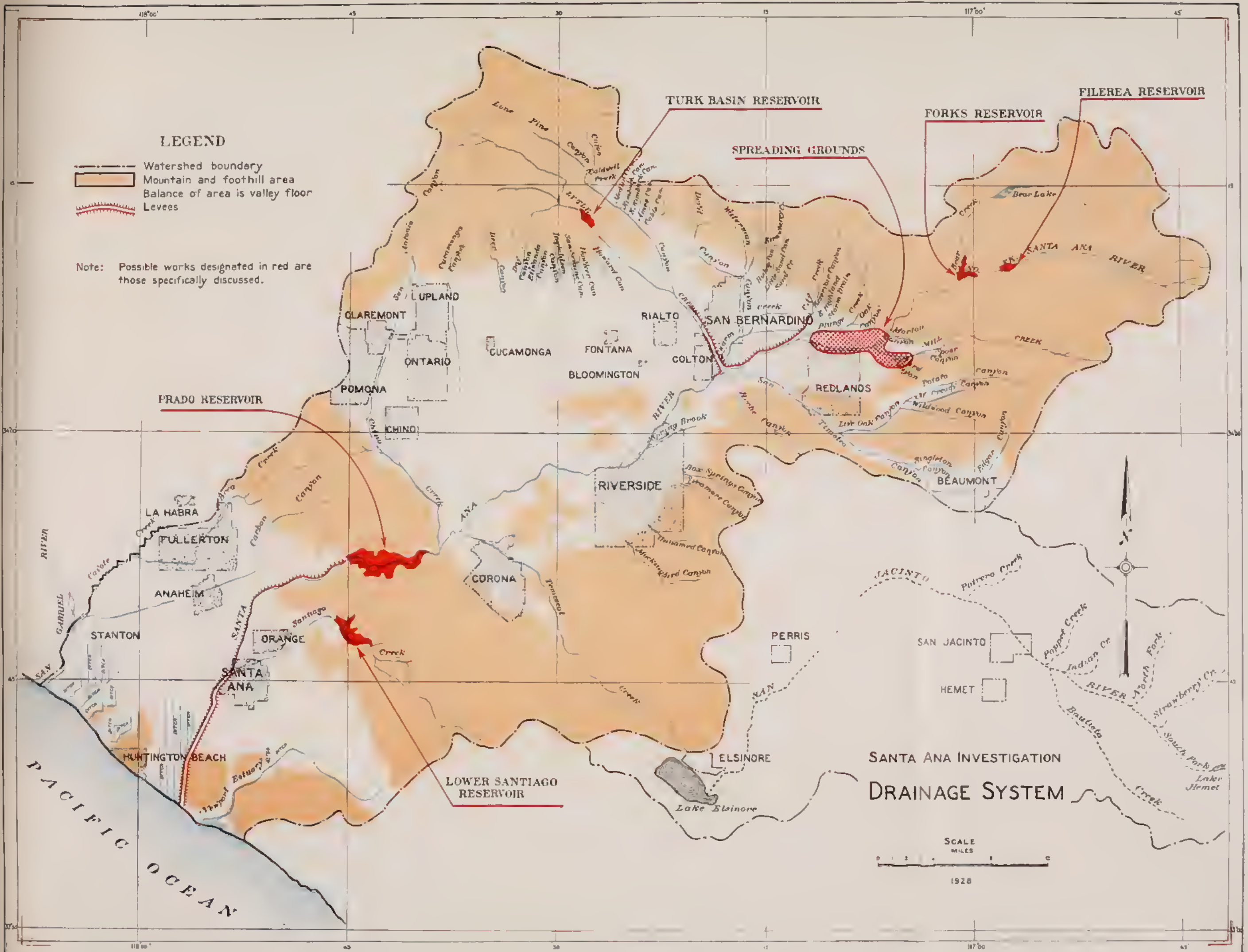
LEGEND
Watershed boundary
Mountain and foothill area
Balance of area is valley floor
Levees
Note: Possible works designated in red are those specifically discussed.
TURK BASIN RESERVOIR
FORKS RESERVOIR
FILEREA RESERVOIR
SPREADING GROUNDS
PRADO RESERVOIR
LOWER SANTIAGO RESERVOIR
UPLAND
CLAREMONT
ONTARIO
POMONA
CHINO
CUCAMONGA
FONTANA
BLOOMINGTON
RIALTO
SAN BERNARDINO
COLTON
REDLANDS
BEAUMONT
RIVERSIDE
CORONA
LA HABRA
FULLERTON
ANAHEIM
STANTON
ORANGE
SANTA ANA
HUNTINGTON BEACH
PERRIS
ELSINORE
SAN JACINTO
HEMET
Lake Elsinore
Bear Lake
PACIFIC OCEAN
SANTA ANA RIVER
SANTA ANA INVESTIGATION
DRAINAGE SYSTEM
SCALE
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at Mentone exceeded certain quantities. In 1910 and 1916 when records were missing they have been estimated by comparison with other streams.

	No. of days since 1896-97	*No. of days in 1915-16*
Average day's flow at Mentone was greater than 1,000 sec.-ft.	57	15
Average day's flow at Mentone was greater than 2,000 sec.-ft.	17	7
Average day's flow at Mentone was greater than 3,000 sec.-ft.	7	3
Average day's flow at Mentone was greater than 4,000 sec.-ft.	6	3
Average day's flow at Mentone was greater than 5,000 sec.-ft.	5	2

Assuming that the peak of the day's flood was $2\frac{1}{2}$ times as great as the average day's discharge, the above table indicates that the spreading works alone would have taken care of the discharge on all but 18 days in the 32-year period, and a considerable part of it in these 18 larger days, of which 7 occur in one year, 1916. This is predicated on the assumption that spreading works will function to capacity of 5000 second-feet. It can not be said with assurance that they will, since such large works are unprecedented. The smaller works that have been constructed have never been operated during the crest of large floods. However, the large works on which this study is based are planned on a principle which is believed will be successful. Estimated cost is $1,100,000 including channel control at San Bernardino.

In view of the unprecedented and novel features of this work it is believed that the first works which it is attempted to install should not seek to divert more than 1000 second-feet.

Filerea Reservoir. This is one of the possible reservoirs in the headwaters. For a capacity of 4000 acre-feet, the height of dam is 178 feet. This is the most feasible capacity, but it can be built higher. The site lies above the portion of the watershed from which most of the debris is derived, and it would thus have longer life than a reservoir lower on the stream. It could be used as a conservation reservoir, as an aid to spreading and with proper manipulation and design it would also aid to an extent on the larger floods, but could not be expected to reduce the peak of the capital flood. Estimated cost is $1,700,000.

Forks Reservoir. This is the second of the possible reservoirs in the headwaters. For a capacity of 20,000 acre-feet, the height of dam is 315 feet. It is below a rapidly disintegrating portion of the watershed and as a conservation reservoir would have a shorter life than the same reservoir situated at Filerea, because of the debris which will be lodged behind it. As a reservoir for flood control only and with ports of sufficient size constantly open, it would be free from this fault and could be expected to decrease the capital flood 10,000 second-feet. Like Filerea it could be used as a conservation reservoir and as an aid to spreading. With proper manipulation and design it would aid in control of the capital flood, but its full use for restraining the capital flood will practically eliminate its utility in the other functions. Planned to function in reducing a flood like that of 1916, it would have conservation features. Estimated cost is $8,000,000.

The small capacity of both the above reservoirs in the headwaters as compared to the flow, makes it impossible to fully combine conservation and flood control, and for either alone they are only partially effective. They can both be built to larger capacity if the benefits are

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The small capacity of both the above reservoirs in the headwaters as compared to the flow, makes it impossible to fully combine conservation and flood control, and for either alone they are only partially effective. They can both be built to larger capacity if the benefits are thought to be sufficient. The cost per acre-foot does not materially decrease as capacity increases.

Channel control near San Bernardino and Colton. This would consist of a single dike running from near the foothills west of City Creek southward below San Bernardino, then west to about E Street Bridge in Colton. It can be made sufficient in size to retain any flood. Estimated cost $700,000. This item is also included in the $1,100,000 estimated cost of spreading works.

Prado Reservoir and channel control below. The following statements and estimates are derived from the chief engineer of Orange County Flood Control District:

> The present channel has capacity of 5000 second-feet to the ocean and a reservoir of 180,000 acre-feet will make it possible to reduce the capital flood approximately to that figure. The cost of such a reservoir at Lower Prado site is $11,800,000 and only small channel improvement is necessary. The cost of such a reservoir at Upper Prado site is $7,600,000 leaving out of consideration the intangible value of water rights which might be lost.

A somewhat more expensive and more complicated possibility lies in constructing Jurupa Reservoir near Riverside for control of the main river, together with reservoirs on the lower reaches of Temescal and Chino creeks, which are the principal tributaries immediately below Jurupa. This would require enlargement of the channel below Lower Santa Ana Canyon to 25,000 second-feet to handle a capital flood, and the cost would be greater than the cost above given for the Orange County Food Control District plan. Conservation and flood control accomplished would be slightly less than attained by the district plan. Similar results could be attained by a smaller reservoir at the Lower Prado site and enlarged channel below, but this also would be more expensive than the district plan.

On Lytle Creek. The works considered consist of Turk Basin Reservoir (5000 acre-feet) and channel control to pass 20,000 second-feet safely at Cajon Creek would still be unregulated. Cost is estimated for reservoir $4,000,000 and for channel control $400,000.

On Santiago Creek. The works considered are Lower or Upper Santiago Reservoir at 24,000 acre-feet capacity. This would completely control every flood but the capital flood, and in that flood would deliver 2300 second-feet to Santa Ana River. The present creek channel will carry this quantity with negligible improvement. Cost $1,200,000.

Summing up. The flood control features would yield the following results:

Above Lower Santa Ana Canyon the estimated effect of the above works on the capital flood at Colton is as follows for the average day's flow:

	Second-feet
Forks Reservoir will decrease capital flood	10,000
Spreading works will decrease capital flood	3,000
Lytle Creek Rerervoir (Turk Basin) will decrease capital flood	2,000
	15,000

Below Lower Santa Ana Canyon the reservoir noted in the Lower Canyon, will decrease the estimated capital flood by 82,000 second-feet for the average day's flow.

Conservation of Water.

The works enumerated will aid in conserving the 33,000 acre-feet of water estimated to waste at present. So far as conservation is concerned the reservoirs are in the main merely structures desirable in the program to force the waste underground and make it available later. The only successful conservation will take a leaf from the book of nature and copy her methods. The task of conservation of the last of the supplies is most difficult, and the process must be more efficient than nature's. Whereas the supplies naturally conserved required about 3 acre-feet of underground storage for each acre-foot salvaged, to store all of the remaining flood waters which are the last and most erratic in occurrence, will require 9 acre-feet of underground space for each acre-foot conserved.

A clearer view of the effect of conservation on the water supplies may be obtained by an approximate estimate of the origin of the 33,000 acre-feet now wasting in the channel of the Santa Ana. Such estimate is as follows:

Origin of Water Wasting via Santa Ana Channel

Average 34 years

	Acre-feet	*Per cent*
From Upper Basin	14,000	42
From Jurupa Basin	3,000	9
From Cucamonga	3,000	9
From Temescal	6,000	18
From Santiago Creek	7,000	22
	33,000	100

While averages are a convenient basis on which to express the broad outline, yet to gain an idea of the works necessary to control the average requires consideration of the run-off of individual years and even days. For example, in the high year of 1916 the estimated waste was 286,000 acre-feet which is considerably more than the average mountain run-off to the valley on the surface. In the year 1922 the waste was 135,000 acre-feet. If the wastes of these two years be taken out, the remaining average waste is 23,000 acre-feet. It is likewise with that portion of the waste estimated to come from Upper Basin. In the above two years it is estimated to be 143,000 and 46,000 acre-feet, respectively. If excluded the average waste of the remainder of the 34-year period is 9000 acre-feet. There are no other years as high as 1916 but on the average one year in five gives discharge far above normal. Although the average is one year in five, the interval between the high years is very irregular.

The problem of conservation lies in getting the water of these exceptional years into the ground in such way that it will be retained long enough to be of use. It is no simple matter but so complex that much more study will be necessary before the problem can be fully solved. The works enumerated will probably enable nearly all the flood escape from Upper Santa Ana Canyon to be retained in Upper Basin temporarily but it is certain that only a part of this water will be retained sufficiently long to be available in that basin or for exportation from it unless the water plane is permanently lowered to make more capacity available. It is believed that two-thirds of the 3000 acre-feet of surface flow estimated to waste from Cucamonga Basin will continue to waste from that basin in spite of the probable spreading which will be done, since a considerable part originates as rainfall on the valley floor and can not be salvaged in the basin. The waste from Temescal Basin is estimated to come partly from overflow of Elsinore Lake and this probably will decrease.

It is evident that with the foregoing works the bulk of the salvage of flood waters will be at Lower Santa Ana Canyon. It is improbable that the water plane in the coastal plain is low enough at this time to impound the wastes of years like 1916 and hold them over for the dry years. In any event it will be difficult to dispose of so much water without merely increasing waste of the water placed underground. Salvage in Upper Basin will aid in this.

Location of Salvaged Waters.

The works heretofore enumerated would, it is estimated, enable a quantity equal over a term of years, amounting to somewhat less than 40 per cent of the waters which now waste into the ocean via Santa Ana River, to be controlled in the basins above Lower Santa Ana Canyon. The remaining 60 per cent would be caused to percolate in the coastal plain if sufficient area of spreading works exist. Most of the 40 per cent which may be retained above Lower Santa Ana Canyon is tributary to Upper Basin, and it will be salvaged in the main by causing it to percolate within the Upper Basin. Although it is controllable in the Upper Basin this does not necessarily mean that it will be retained and used there. The large amounts which come in the wet years and the limited capacity of Upper Basin militate against this and it is believed that the surplus salvage of the wet years will find its way down river within two or three years after being salvaged. Therefore it is probable that a part of this would reach the coastal plain even if detained for a time in Upper Basin. The estimated 32,000 acre-feet wasted into the ocean along the fringe of the coastal plain or evaporated from moist lands in the coastal plain will of course be used there, if it can be salvaged. The eventual destination of the 20,000 acre-feet estimated evaporation in Upper Basin and the 15,000 acre-feet estimated evaporation along the river bed from Colton to the lower end of Lower Santa Ana Canyon will be decided by the future, and this report only concerns itself with pointing out that wastes do exist in the localities mentioned.

Protection of Flood Control Works.

The valleys are filled by erosion from the mountains and the streams have wandered widely over them. Flood control works are for the protection of the works of man and if successful will hold the water to a narrow permanent course. Future erosion from the mountains will be deposited only in this channel instead of over the wide plain, and hence flood control tends to defeat itself because it changes the processes of nature. The reservoirs in time will fill with debris. The best works that can be constructed are thus limited in length of service because of the constant erosion from the mountains. Flood control works must therefore themselves be protected. Rights of way along channels must be wide enough to give opportunity for storage of materials brought down by successive floods and which must be excavated from the channels. Erosion rate may be decreased by check dams in each smallest mountain gulch beginning at the extreme head. This matter deserves much further study.

Increasing Water Supply.

On the average it is believed that the more prolific area of the mountain watershed transpires about two feet in depth of water in the average year. It is reasonable to assume that if the average size of the vegetation or the average leaf surface per acre were smaller less water would be thus lost and that the water saved from transpiration in the mountains would reach the valley and augment the supply for valley lands. Methods of safely effecting such reduction in consumption of water in the mountains are worthy of serious study by the proper authorities in view of the great need for additional water.

There is also the possibility, fully discussed in the report, of additions to the supply from outsde the watershed by utilization of sewage and the Colorado River Aqueduct.

SUMMARY OF COST ESTIMATES

The following table shows features reported on during the course of the investigation without regard to their feasibility. Each feature is discussed on other pages of this report as noted below.

Feature	Stream	Height of dam in feet	Capacity of reservoir in acre-feet	Estimated cost		Page reference
				Per acre-foot of capacity	Total	
Reservoir sites						
Blue Diamond	Temescal Creek	160	81,500	$50	$4,081,000	59, 72, 87, 89
Blue Diamond	Temescal Creek	110	31,000		1,600,000	88
Chino	Chino Creek	75	39,000	82	3,200,000	60, 89, 150
Crafton	Mill Creek	305	16,000	585	9,000,000	56, 150
Declez	Near Fontana	45	9,500	113	1,100,000	58, 69
Declez	Near Fontana		65,000		4,847,000	59, 89
Filerea	Santa Ana River	178	4,000	421	1,700,000	19, 55, 62, 89, 148
Forks	Santa Ana River	310	19,600	407	8,000,000	19, 56, 63, 84, 87, 88, 149
Hemlock	Santa Ana River	255	12,200			56, 149
Highland	City Creek	300	6,000	526	3,100,000	56, 148
Hot Springs	Lytle Creek					57
Irvine	Near Newport	40	16,800	15	242,000	61, 89
Jurupa	Santa Ana River	85	65,000	113	7,300,000	59, 71, 87, 88, 150
Keenbrook	Cajon Creek	180	16,600	325	5,400,000	56, 148
Kelly Lake	San Antonio Creek					57
Little Mountain	Near Devil Canyon	50	2,600	370	964,000	58, 68
Little Mountain	Near Devil Canyon	150	72,800			58, 89
Mentone	Santa Ana River	310	25,000	760	19,000,000	56, 149
Myer	Myer Canyon	157	5,000	400	2,000,000	57, 65, 89
Narrows	Cucamonga Creek	270	3,500	865	3,000,000	57, 147
Ontario	San Antonio Creek	250	9,200	570	5,300,000	57, 147
Prado (lower)	Santa Ana River	155	180,000	62	11,800,000	20, 60, 151
Prado (upper)	Santa Ana River	93	180,000	42	7,600,000	60, 74, 84, 86, 87, 151
Red Hill	Cucamonga Creek	60	1,000	617	617,000	58, 70
Santiago (lower)	Santiago Creek	110	23,600	51	1,188,000	61, 73, 84, 87, 88, 89
Santiago (upper)	Santiago Creek	137	32,000	69	2,215,000	61, 89
Sierra	San Antonio Creek					57
Singleton	Singleton Creek	80	5,500	200	1,100,000	58, 67, 89
Slide Lake	Bear Creek					56, 117
Sunset	West of Camp Baldy	30	700			57
Turk Basin No. 1	Lytle Creek	268	22,700	340	7,700,000	57, 147
Turk Basin No. 1	Lytle Creek	155	5,000	496	3,970,000	20, 64, 84, 87, 88
Turk Basin No. 2	Lytle Creek					57
Yucaipa	Live Oak Creek	110	7,500	198	1,500,000	58, 66, 89

SUMMARY OF COST ESTIMATES—Continued

The following table shows features reported on during the course of the investigation without regard to their feasibility. Each feature is discussed on other pages of this report as noted below.

Feature	Location and description	Estimated cost	Page reference
Spreading works			
Anaheim Channel	Yorba to Alamitos, including rights of way	$1,000,000	78, 79, 88
Cucamonga	Additional development to present works	150,000	78, 165, 168, 169, 170
Day and Etiwanda	Additional works on Day and Etiwanda creeks	50,000	78, 165
Lytle Creek	On east side, additions to present spreading works	100,000	77, 165, 171, 172, 173
Lytle Creek	On west side, new development	500,000	77, 78, 88
Mill Creek	Development, exclusive of lands	270,000	77, 88, 165, 177, 178
Santa Ana Cone	Development, exclusive of lands	1,100,000	19, 76, 88
Canals			
Chino	Jurupa Reservoir to Chino Reservoir	775,000	80
Conservation	Jurupa Reservoir to Lower Santiago Reservoir	3,000,000	80, 89
Deciez	Santa Ana River to Deciez Reservoir	2,465,000	79
Gage	Extension of canal for 7 miles to Blue Diamond Reservoir	500,000	80
Irvine	Santa Ana River to Irvine Reservoir	150,000	80
Little Mountain	Little Mountain Reservoir to spreading grounds	80,000	79
Salvage	Chino Creek to Anaheim and Santa Ana canal headings	300,000	80, 89
Channel control works			
City Creek	Gravel levee with wire mattress, 40,000 linear feet	704,000	82, 84
Lytle Creek	Single levee with wire mattress, 6,000 linear feet	100,000	82, 84
Lytle Creek	Double levee on relocated channel, 10,000 linear feet	430,000	82, 84
San Antonio Creek	Flood control levees below spreading works	150,000	78, 84
Santa Ana River	Double levee at Colton	100,000	82, 84
Santa Ana River	Single levee Yorba to Santa Ana, 90,000 linear feet	1,500,000	82, 84
Santa Ana River	Widening of lower channel and levee protection	3,500,000	82, 83, 84, 86
San Jacinto and Perris	Channel control by levees, 10,000 linear feet	150,000	83
San Timoteo Creek	Double protected levee, new channel, 27,000 linear feet	600,000	82, 84

PART I

DISCUSSION AND ILLUSTRATIVE SOLUTIONS

CHAPTER 1

INTRODUCTORY

The mission of the investigation, under the terms of the legislative act is, "To determine the method of and the construction of works for controlling the floods of the Santa Ana River and its tributaries." The final work of assembling the data gathered during the investigation was actively taken up in October, 1927, and by the terms of the last legislative act was completed on December 1, 1928. In presentation it was decided to publish the voluminous mass of collected facts for public use, irrespective of whatever form future action might take. Flood control is a matter for public bodies, and combinations of structures to secure it are discussed. Conservation, more a matter of benefited area, is set out separately.

Of the three counties cooperating financially with the state in this report, Orange County had an existing flood control district organized, the counties of Riverside and San Bernardino had not, but were understood to be withholding action until the publication of the report. Each county by resolution of their board of supervisors had appointed advisory engineers, representing each county, to whom all the collected data and the text of the report was submitted by this office.

On October 19, 1928, a formal presentation of the plan of Orange County Flood Control District for flood control in Orange County was made to the legislative committee of the state legislature. The public press further announced that a bond issue on this plan would be soon placed on the ballot. At the time of the publication of this report, therefore, one of the counties has already tentatively announced its plan of flood control.

The greatest service which can be given is to indicate the complete development of flood control and conservation common to the entire watershed whether or not joint action of the various counties is indicated. A unified plan of development could wisely be adopted in principle, to anticipate structures, some of which need not be built for many years. An example of such a plan is the 1912 Report of the California Debris Commission for flood control on the Sacramento River. Until this report was adopted in principle, there had been no correlation of levee construction or of reclamation. After that date no levee or reclamation project was authorized unless it conformed to the plan of the Debris Commission Report of 1912. This is the idea of the comprehensive plan. The plan itself may not be perfect; it may receive revision from time to time. It, however, places unrelated units in relation. A unit authorized thereafter will be correlated in its anticipated results and in its effect on future units throughout the watershed.

This report is published at the time when the special legislative committee on water resources is engaged on a statewide inquiry of the needs of various localities and is formulating recommendations as to comprehensive development. This adds to the significance of the original purposes of the report. At the outset it is well to set down certain general points, resulting from the present study.

Floods are a menace to life in two localities in the watershed; at Colton and at Anaheim.

Floods are a menace to public highways and utility crossings throughout 80 miles of the main Santa Ana River and 50 miles of major tributaries.

Floods create damage to riparian property over a length of 130 miles of stream frontage. In addition 100 square miles not contiguous to the channels are liable to property damage by escape from levees or possible changes of river course.

By a selection of the works hereafter described it is possible to confine and regulate these floods to safe quantities. Several combinations of works may be selected, any of which may accomplish flood control.

The utilization of water of today with the present natural losses and waste, is estimated to exceed by 22 per cent the safe draft. Safe draft is defined as the dependable quantity which may be furnished continuously throughout the driest cycle of years. It implies a 100 per cent draft in every year.

Conservation works can be constructed which would store the waste into the ocean and salvage natural losses to the extent of an estimated 100,000 acre-feet. Were these works constructed, the utilization of today would be practically at the limit of safe draft. Additional use on present lands or use on new lands would result in deficiencies in certain years, or a draft on ground water capital, not replacable.

Additional use on present lands or use on new lands beyond the safe draft, requires imported water. Two sources of imported water are suggested in this report.

In the future development of works for flood control and conservation, several combinations of works may be selected which will accomplish these purposes. It is recognized that such a solution must be affected by local conditions, political boundaries and financial questions. Keeping this in view, it is probable that it will be necessary that the counties confer on a comprehensive plan of flood control and formulate a complete future program, suitable to political, economic and technical conditions, under which units described in this report may be selected and designated for construction. The subject matter of such a plan is outlined in the following paragraph.

A comprehensive program to be adopted in principle covering the fullest ultimate development. This plan would be a guide for the adoption of single units which would be from time to time proposed and constructed. This comprehensive plan would be modified from time to time as additional information became available, but would remain the ideal towards which all efforts would be directed.

The comprehensive plan should include:

(1) Channel easements, held by the district.
(2) Flood control dams.
(3) Check dams.
(4) Bank protection from floods.
(5) Flood spreading works.
(6) Conservation by surface storage.
(7) Conservation by underground storage.
(8) Conservation by salvage through the elimination of moist areas.
(9) Conservation by storage of winter water for use in summer.
(10) Conservation of power.
(11) Importation of outside waters.

The comprehensive plan includes ample waterways for passing maximum floods on the Santa Ana and all of its tributaries. These easements would not prevent the limited occupancy of the land.

Dams for flood control in the upper Santa Ana watershed should be true flood control dams, designed to reduce the extraordinary high peak floods of this region to a more nearly uniform flow. In view of the danger of insufficient operation and management the combination of flood control and storage is considered inadvisable. Permanent openings without gates will guarantee their utilization for the purpose designed.

Check dams are still in the experimental stage. It may be properly indicated that permanent construction only should be tolerated. There can be little doubt that construction involving rusting wire is a serious menace, resulting in an accumulation of debris liable to greater destruction than without such construction. Substantial concrete cribs or solid concrete weirs are advisable in any event. As the cost is moderate, a continuing policy of careful experiment and observation of effects, would be justified with the reasonable anticipation of beneficial results.

Bank protection is necessary to confine the migratory portion of the streams. As certain portions are sections for deposit of debris, maintenance provision must be made for additions to levee heights.

Spreading of flood waters as a flood control measure has the merit of dispersing the concentrations of floods. Concentration means rapidly increasing velocities and still more rapidly increasing power to transport debris. Distributing floods over favorable cones would result in detaining tops of peak floods and securing a distributed time element in the arrival of the waters on the valley floor produced by excessive but not continuous precipitation.

All flood control works should be designed to aid conservation, and be coordinated with it.

Conservation surface reservoirs should be sought high on the watershed, to avoid excessive debris deterioration. Otherwise they should be sought below flood control reservoirs to benefit by their regulatory action, and preferably placed off of the main drainage lines, to decrease debris deterioration and to decrease the danger of damage by flood. In the Santa Ana watershed it is possible to utilize surface reservoirs on porous ground where absorption into gravels may take place.

Underground storage is clearly the main resource of conservation in the future as it has been in the past. It should be considered as fundamental. In the past it has furnished 95 per cent of the storage, and in the future the main effort should be so directed. The flood control reservoir makes additional underground storage possible. Flood water spreading assists it further. Effective conservation requires a further intensive system of spreading sufficient to ensure getting the water into the ground, after reservoirs and other works have furnished the means of getting hold of it. Survey should ascertain where efficient storage may be secured. Excessive moist areas below underground storage indicate an excess of natural absorption or spreading. Such areas may be relieved by spreading their surplus waters in areas where such losses would not occur.

Surface storage reservoirs designed for storing winter flow, whether eventually absorbed in the lower reaches of the stream or diverted by reason of its being in the stream and not because such application is preferable, would accomplish conservation in several senses. It provides the desirable rather than the fortuitous application of irrigation water. It may remove water from water courses subject to useless evaporation. It may conserve at higher levels water which may be utilized more frequently in successive reuse in its descent to the ocean. It may assist in recovery of power.

Power conservation will arise from over-year storage and from annual storage in surface reservoirs. Power may be obtained by canalization of the river now permitted to flow in natural water courses.

A complete development program should consider what outside waters are available, and in what way they should be coordinated with that available within the watershed.

These should be the general objectives toward which public bodies should work. Illustrative combinations of the many units described in this report indicate what may be accomplished.

CHAPTER 2

GENERAL SITUATION

Physical and Economic Situation.

The watershed of the Santa Ana River has a total length of 100 miles and drains 2050 square miles. Of this 1196 square miles are mountains, foothills and isolated hills and 854 square miles are main valley floor. Thus, 42 per cent of the entire watershed is in gravels, sands and silts, generally water absorbing and water bearing. Of the 1000 square miles of habitable area, 508 square miles are in San Bernardino County, 159 square miles in Riverside County, 323 square miles in Orange County, and 10 square miles in Los Angeles County.

Of the total habitable area, 342,700 acres are now under irrigation; 25,282 acres are in domestic use; 21,218 acres are in river beds and waste lands; and 225,800 acres are usable in the future. The rate of increase of domestic and irrigation area for the historic period is 8000 acres per year, and apparently for the last eight years, 21,000 acres per year.

The assessed valuation of the habitable area is $263,000,000. Within it are operating 78 water organizations with a total service area of 191,500 acres, some with use dating back a half century. In addition 207,100 acres are occupied by unorganized individuals.

Within this area major constructed works and pumping plants and distribution mains of enormous cost have been constructed. Of the water organizations, 62,900 acres are dependent primarily on surface diversions, although utilizing auxiliary pumping, 37,200 acres are dependent entirely on pumping from the ground water, 46,300 acres are served by both surface diversions and pumping, 207,100 acres of individuals are served almost exclusively by pumping. The mean horsepower during maximum month utilized by electric and gas installations is 35,000, and the total annual requirement is equivalent to 100,000,000 kilowatt-hours annually.

The general technical and economic situation is that of a highly organized and long established community, with enormous investments in water property and whose income is identified with the use of water. The area has been completely mapped topographically. Numerous instrumental and statistical surveys have been made. A mass of technical and economic information exists. Trained managers, engineers and attorneys have investigated time and again almost every phase of the water situation as to particular enterprises. The pioneer period has long since passed. A complex system of works and interrelated interests has arisen.

Interests affected. To the old established user, the problem is to find that additional water required by trees as they mature.

To all operators of pumping equipment, the problem of lowering water table is present. It, like the weather, is not only a perennial topic for conversation, but also like the weather, is not entirely under control of the individual. Certain phases of the problem are easily ascertainable; the level of the water table and its variations year by year, the approximate pumpage, the return water and the import and export for given boundaries of underground reservoir. Other phases are less easily ascertainable; the source of the supply, the rate of approach to the point of use from such source, and how the fluctuations of water levels are related to decrease or increase of supply at source. The pumping operator, and frequently the gravity user, is in the same case as the oil operator. He is subject to the problem of the "offset well." He is subject to the competition in extraction of the new operator. This competition may and frequently does fall under that class of legal conceptions, where damage occurs without legal redress.

To the community at large, the problem of normal increase in wealth and appreciation of values, extension of urban population, the additional business and manufacturing enterprises required in an advancing territory, calls for adequate water supply responsive to the demand.

To all of these, the problem is a correctly controlled and maximum use of water. In the actual development of these objectives, as between individual interests, often arises only a struggle for control of an insufficient supply and recourse to the favorite indoor sport of California, the lawsuit. Seldom is increase of the quantities available to the community accomplished by these disputes, and they constitute a community financial loss analogous to wasting water by evaporation or sluicing it into the sea.

Control of water to secure a maximum supply at costs determined by the economic situation is the engineering problem, and that problem is solvable.

Ahead of the engineering accomplishment is the engineering of men. The decision of the community at large must be made. For accomplishment, its public bodies, its semipublic water organizations, and its individuals must unite in team work to pool, rearrange and compromise existing interests, to legislate and to create a competent organization to carry out the engineering solution.

This report presents engineering possibilities, with the probable results to be obtained and their cost. It can not forecast the decision of the community, but it intends to present in sufficient detail the very numerous units which are more or less feasible, and illustrative combinations for the consideration and selection of the community.

Recent Physical Observations.

The engineering investigation has developed certain elements which have only recently been given quantitative values and which tend to modify preconceived views. These are the mechanics of rainfall on the valley floor, the transpiration and evaporation from unused lands, evaporation from flowing natural channels, the evaporation losses from moist areas, and the over-year storage of water in gravels.

Stream measurements at the mouths of canyons determine that portion of the supply entering the valley floor from the mountains. The cooperative investigation of the U. S. Department of Agriculture has given a basis for a tentative determination of the net contribution to ground water from rainfall upon the valley floor itself. That such a determination is an important element of the problem is illustrated for instance by finding, on the above tentative basis, that in the Cucamonga

Valley rainfall in the season 1926-27 contributed 38 per cent of the total supply, while stream flow from the mountains contributed 62 per cent.

Transpiration and evaporation from land now unused, but suitable for agriculture, must be determined for comparison with conditions after it is put to use and to forecast the net additional water required for the new land, if any. A natural uncultivated growth of grass, weeds and brush continues to exhaust the moisture from the soil throughout the summer so that uncultivated land is in an extreme state of dryness to a considerable depth at the beginning of each rainy season. This amount of moisture which would have been used by the natural growth must be subtracted in obtaining the net increased draft on the water supply caused by placing land under irrigation. Considering this factor and the return waters from irrigation, the increased draft on the water supply due to irrigation of new land is estimated to be not more than one acre-foot per acre although the gross application may be as high as two to two and one-half acre-feet per acre. Certain crops, notably grapes, probably cause no additional draft on the water supply, since the consumptive use is no greater than the natural losses.

Evaporation from flowing natural channels and transpiration from trees, dwarf willows and grasses bordering these channels, has been estimated to be practically the same as that from a free water surface, and the prevention of these losses is one of the methods of increasing useful water supply.

The theory of evaporation from moist areas has been modified by recent observations. In past experiments and reports under the term "Evaporation," often transpiration by vegetation was included. Now a sharp distinction is drawn between evaporation and transpiration.

On the coastal plain an area of 100 square miles was originally moist. Gradually the water plane has lowered and the cultivated area has extended so as to practically cover all the areas formerly moist. Part of this cultivated area is in orchards and the remainder is devoted to annual crops. Under the present conditions this territory has been converted from the original situation of large losses from soil evaporation and transpiration by such natural cover as existed to a situation in which the cultivated lands have no greater losses than cultivated lands elsewhere. The natural losses have been converted into useful consumption. The major portion of the moist area west of Anaheim and Santa Ana has been tile drained during the last twenty years, or drained by deep ditches. The effect of such drainage has been to establish a water plane which does not rise above four to six feet from the surface. Recent observations tend to show that the summer consumptive use for natural cover is entirely transpiration, and equals or exceeds the possible capillary rise. Soil evaporation originating from the water table, is considered to be absent where vegetation is present. This is demonstrated clearly on those fields where irrigation is found to be necessary in spite of the fact that the water plane is within six feet of the surface. It should be clearly understood that the water plane referred to, is the level of the so-called perched water lying closely beneath the surface, and not related to the water obtained from deep wells, which may be artesian or semiartesian, and which show an entirely different elevation of water levels.

The moist area near San Bernardino is not an identical situation to that in the coastal plain. The moist area here is closely related to the artesian pressure. Yet ordinary drainage would serve to lower the water table to such an extent as to reduce evaporation and transpiration.

An important element was the determination of the volume of water actually effective in over-year storage in gravels. It has been found to amount to 1,500,000 acre-feet. Existing surface storage is only 5 per cent of underground storage. It is certain that the lowering of levels in wells, while a serious matter for the individual pump operator, provides additional space for underground storage in wet years. It actually may increase the water supply available to the individual and certainly the amount available to the community. The engineering problem is to provide for the storage of the waters in wet years, now finding their way only by chance to overpumped depressed gravel areas. An additional problem is modifying the gravel storage on cones which receive such quantities as to have a moist evaporation area at their bases. The ideal underground reservoir is without evaporation loss. If its waters appear at the lower end and evaporate, to that extent it is inefficient. The solution of this class of wastes is in some instances being accomplished unconsciously by the very excessive pumping and lowering of water table, which concerns the individual operator so seriously.

CHAPTER 3

OUTLINE OF PROBLEMS

Fundamental Distinctions.

In the use of surface reservoirs three distinctions stand out depending directly on the purpose for which they are used. A surface reservoir used for flood control receives the maximum floods, regulates their flow, and is empty again in a few days, ready to receive another flood. A reservoir used for over-year storage is operated in precisely the opposite manner. It must be of large capacity, receiving surplus waters in the wet years, discharge only for consumptive use and hold the waters of wet years for use in lean years. The capacity of over-year storage reservoirs must be from six to nine times the quantity used annually. A reservoir used for annual regulation would hold winter water for use in the summer irrigating season. It might hold 40 per cent of the quantity annually used, but would not provide over-year storage.

Underground storage reservoirs, whether fed by natural absorption or artificial spreading, are essentially over-year storage reservoirs.

The Problem Stated.

The problem of flood control is to eliminate the danger to life at Colton due to Lytle Creek and at Anaheim due to the Santa Ana River, to prevent overflow of a wide area and damage to bridges, utility crossings and riparian lands throughout the length of the Santa Ana River and some of its tributaries. The acquirement of easements is necessary to prevent encroachment on required channels on which protection works may be built and to permanently salvage and benefit riparian lands.

The problem of conservation is primarily concerned with retaining within the watershed 33,000 acre-feet of storm water which on the average in the past 34 years wasted into the ocean. The present average retention for the past 15 years of waters, usefully used or evaporated in moist lands or channels, is estimated to be 474,000 acre-feet. To accomplish this retention there is found to be storage, surface and underground, effective on the watershed of 1,523,000 acre-feet. That is to say, to secure the regulation as of today, effective storage of 3.20 acre-feet for each acre-foot used annually has existed to equalize the storm flows to the present extent. In other words, storage existed amounting to 320 per cent of the average gross yield. The problem of conserving the 33,000 acre-feet of storm water now wasted into the ocean is therefore a problem of providing a storage capacity of considerably more than 320 per cent of this amount either in surface or underground reservoirs, as it is well known that increasingly greater storage must be provided to conserve the last portion of the waste than the first. Calculations indicate that the storage of the waste of the maximum flood year requires 286,000 acre-feet of storage, or 866 per cent of the amount to be equalized.

The problem of conservation should also deal with the retention of water flowing in the winter, now applied to lands during the winter because of the conditions of the supply, and not because such application is desirable. This is the problem of annual regulation. It applies primarily to systems with surface diversions from live streams with little or insufficient surface storage. It is estimated that 40 per cent of the water of the gravity canals is diverted outside of the period of ideal use.

This problem does not apply so obviously to the pumping plant. The pumping plant entirely independent of gravity supply is designed for its maximum monthly and daily requirement. The auxiliary pumping plant used in connection with gravity supplies would be relieved to a certain extent by winter storage of the gravity portion, or its usefulness would be increased at the summer maximum.

Another problem is the salvage of waters now evaporated in moist lands and in river channels. The natural losses in river channels is estimated at 15,000 acre-feet. The replacement of the natural channels by canals would result in conservation.

The problem of moist areas and excessively subirrigated lands is in some instances working out its own salvation by reason of the lowering of surface water plane due to increase of pumping or by drainage ditches. This has occurred in the shrinking artesian area at San Bernardino, Chino and the coastal region. While the wastes are still large, perhaps 30.000 acre-feet, the problem is largely local, and the community is interested primarily only in the conversion to use of waters now wasted. Drainage ditches, now discharging into the ocean, are subject to salvage to extent of possibly 9000 acre-feet annually.

Another problem is inherent in the original planning of systems, based on legal rights and necessity rather than engineering plan. In so far as the diversion and use may be placed near together, economics if not law would be served. The sequence of return waters would be improved and conservation would be increased. Pooling of conveyance facilities and pumping facilities would be of economic value.

To summarize, the problem is to consider the provision and operation of about 286,000 acre-feet of storage, so that, over a period of time, it will not deprive any area of its accustomed benefits, and will at the same time enable a proper distribution of the salvaged water. This would result in conserving 33,000 acre-feet of storm water now wasting into the ocean via Santa Ana River. In addition, 2000 acre-feet of storm water from Carbon and Brea canyons, 12,000 acre-feet of drainage water and Orange County sewage and 8000 acre-feet estimated underflow wasting into the ocean can possibly be salvaged. To this should be added the salvage of water evaporating in river channels 15,000 acre-feet, and salvage of evaporation in moist lands of 30,000 acre-feet. The maximum possible addition to the future useful supply, therefore, appears to be about 100,000 acre-feet.

The statistical tables in this report indicate an historical increase of acreage in the Santa Ana Basin of 21,000 acres per year in the past eight years. Whether such increase continues or not, it would not seem to have a bearing on this conservation figure of 100,000 acre-feet. Additional pumping increase on new land without storage would apparently merely draw from other existing users. The 100,000 acre-feet will continue to be lost, unless flood and conservation works of some kind or another are constructed.

The safe annual beneficial consumptive use under conditions as of today over a 34-year period, covering the driest known cycle, is estimated at 298,000 acre-feet. The estimated present consumption is 381,-000 acre-feet, or 83,000 acre-feet more than the present safe draft. It appears from these estimated figures that under present conditions of natural loss and waste, the present use has already exceeded the safe draft, and is resulting in an over-draft on ground water capital. If 100,000 acre-feet annually of natural loss and waste be salvaged, this present over-draft would be compensated for.

The tables in this report show an unirrigated or unoccupied area of 226,000 acres. The supply for these 226,000 acres will have to be sought elsewhere. Outside sources are the sewage of the metropolitan area of Los Angeles County and the Colorado River project. The problem of Los Angeles sewage consists in sanitary and esthetic considerations and expense. It would be sufficient in quantity to supply 50,000 unirrigated acres in Orange County, and also provide additional quantities for present users. The remaining lands without water in San Bernardino and Riverside counties appear to be dependent on the Colorado River supply.

The Hydrographic Situation Stated.

The region is subject to great variation in water supply year by year. The mountainous regions vary from 3.7 times the average to one-fifth of the average, or in other words, the annual supply of the maximum season is 18 times the supply of the minimum season. The effect of the absorption by the gravels, sand and silt is however so regulatory, that this variation in the Lower Santa Ana Canyon is reduced. Here the variation is from 3.2 times the average to one-half of the average, or the annual supply of the maximum season is 7 times the annual supply of the minimum season.

The total gross water supply of all kinds, that received from the mountains and the effective rainfall upon the valley floor within the watershed, is estimated to be 446,000 acre-feet annually for a 34-year average; for the past 15 years 543,000 acre-feet average. An amount of 4000 acre-feet exported is nearly balanced by that imported from San Jacinto Basin. The amount escaping into the ocean from all sources, storm run-off, drainage and underflow is estimated to be 55,000 acre-feet for the 34-year period and 68,800 acre-feet on the average for the past 15 years. Beneficial consumptive use as of today is estimated at 381,000 acre-feet. That is, 70 per cent of the estimated average gross supply during the past 15-year period is now beneficially consumed, or 85 per cent of the estimated 34-year average supply.

From the earliest times the middle and lower Santa Ana River maintained perennial flow in its channel. This condition was initially due to the great gravel areas acting as sponges to absorb and regulate the waters of the storm period. Artificial works, the reservoir and the pumping plant have thus far made no essential change in the summer regimen. Surface diversion as from the early eighties is much the same.

On the other hand the increased cultivation of land and the depressions in water level produced by pumping have probably increased the receptivity of the watershed; and probably have decreased the winter flow and the amounts wasting in winter into the ocean.

It is essential in attaining a view of the mechanics of the river to recognize the succession of basins beginning in mountain watersheds, followed by gravel cones and gravel filled valleys, closed by barriers as the Bunker Hill Dike, and constrictions as the Riverside Narrows, the Lower Santa Ana Narrows, and the coastal Dominguez ridge. Between each constriction are gravel filled valleys acting as underground reservoirs, and areas of intensive irrigation where water is put to use, partially consumed and partially sinking again as return water to underground storage.

In this report, the hydrographic studies have been made for each of the following basins: the Upper, Jurupa, Cucamonga, Temescal, and Lower basins. See Plate 1, facing page 12. By this segregation, it is more nearly possible to trace the effect of a future work upon the balance of the watershed, and assign the sources of origin of water supply. It must be recognized, however, that the figures deduced are indicative rather than conclusive, for the extremely obscure conditions and the small residual quantities which are dealt with give large opportunities for error.

In order to visualize the distribution of water supply, its areas of consumption, and its passage from one basin to another, diagrams are presented for the hydrographic situation in 1926-27 and 1927-28, in plates B and C. The blocks represent the valley floor of the basins, and what happened within them during the season. Certain waters were expended in beneficial use or evaporation and transpiration from moist areas briefly designated in the plates as "Consumptive use and loss." Certain other waters were stored, and designated "Placed in storage." The lines with arrows indicate the input reaching each basin by stream flow, by underflow, by rainfall on its valley floor, or by importations; or conversely, the escape from each basin by stream flow, underflow, or exportation.

Plate B, for the season 1926-27, shows in all basins that waters of that season's high supply were put into over-year storage, after all consumptive use had been accounted for. Plate C, for the season 1927-28, shows that all basins drew from past storage in order to maintain the consumptive use and losses. In the Upper Basin, input was less than escape, resulting in drawing on past storage not only for the consumptive use and evaporation losses within the basin, but also to provide the escape by natural stream flow and exportations to basins below.

The Santa Ana River is notable for the perennial flow of Warm Creek at San Bernardino, rising waters near Riverside and additional rising waters between Pedley Bridge and Prado. Plate D, facing page 40, shows graphically the flow of the three summer months of July, August and September at two points, Prado and Pedley Bridge, and also the difference between them which represents the amount of rising water entering below Pedley Bridge and above Prado. The values from which this diagram is platted, are given in Part III, page 357. For the historic period perennial water at Pedley Bridge has been approximately two-thirds of the flow at Prado.

The observations of depths of water in wells made by this investigation will not be published in this report, but are to be published in full in "The Coordinated Plan of Water Development in Southern California," Bulletin 17, 1929, Div. of Engr. and Irrigation, Dept. of Pub.

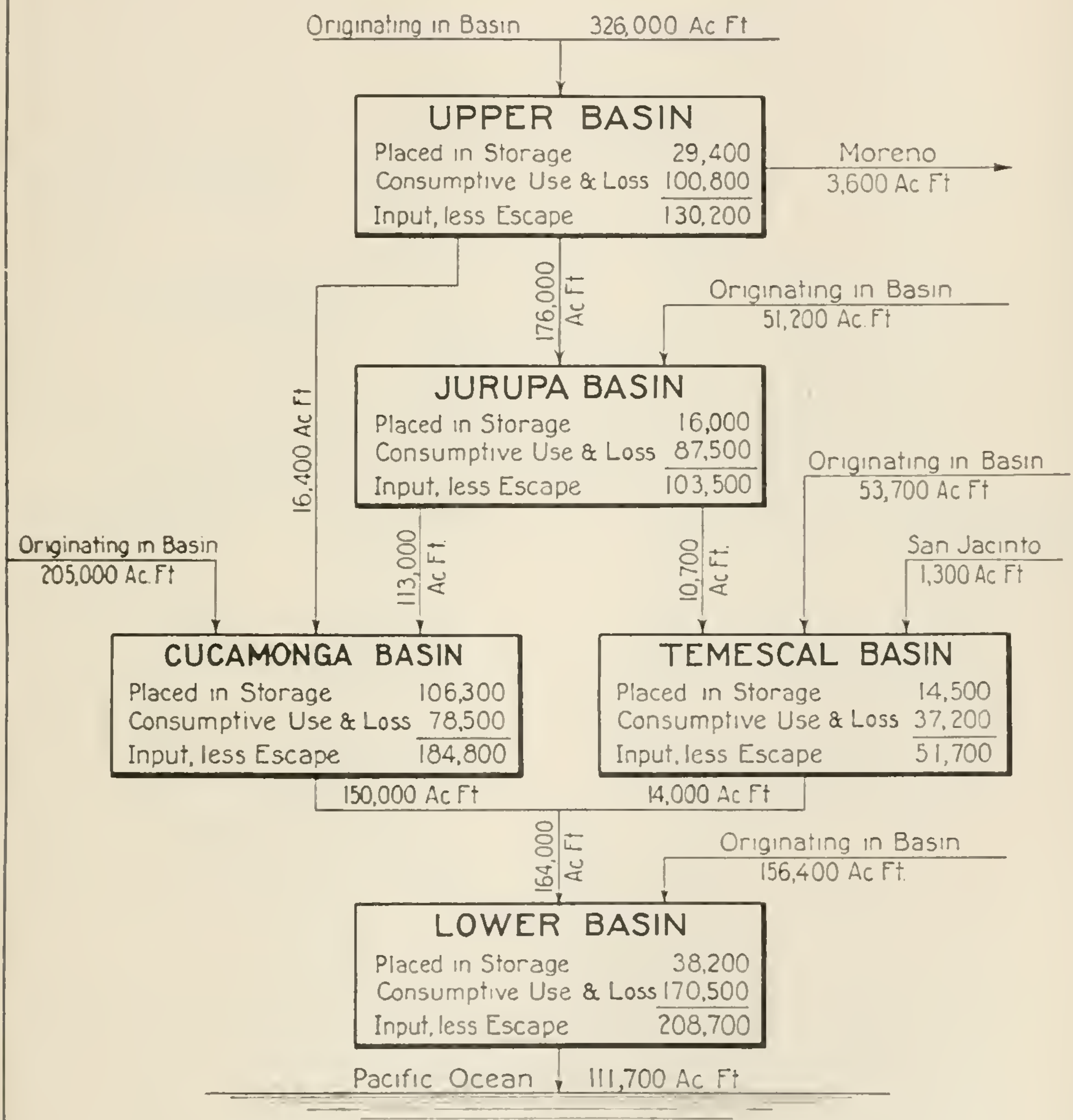
PLATE B

HYDROGRAPHIC DIAGRAM

Showing

INPUT FROM ALL SOURCES, ESCAPE OF ALL KINDS, AND CONSUMPTIVE USE AND WATER STORED FOR THE SEASON IN EACH BASIN.

1926 - 1927



SANTA ANA INVESTIGATION

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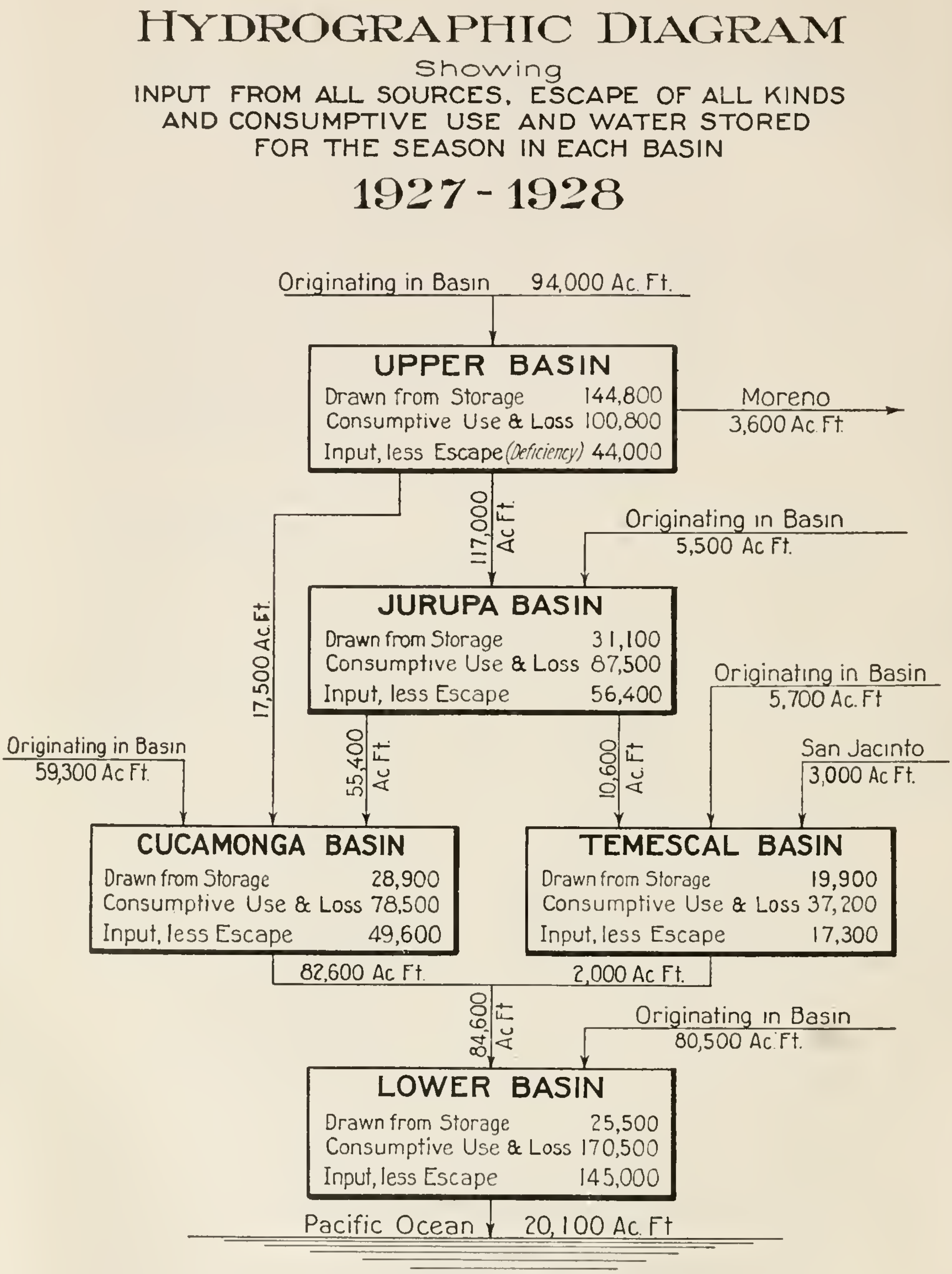
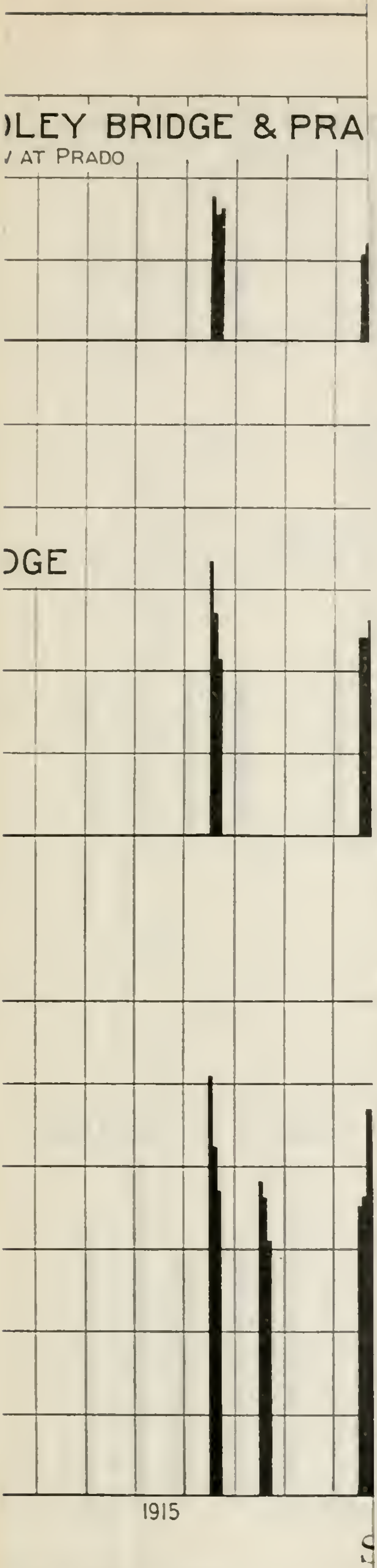
PLATE C



SANTA ANA INVESTIGATION



)LEY BRIDGE & PRA
/ AT PRADO
)GE
1915

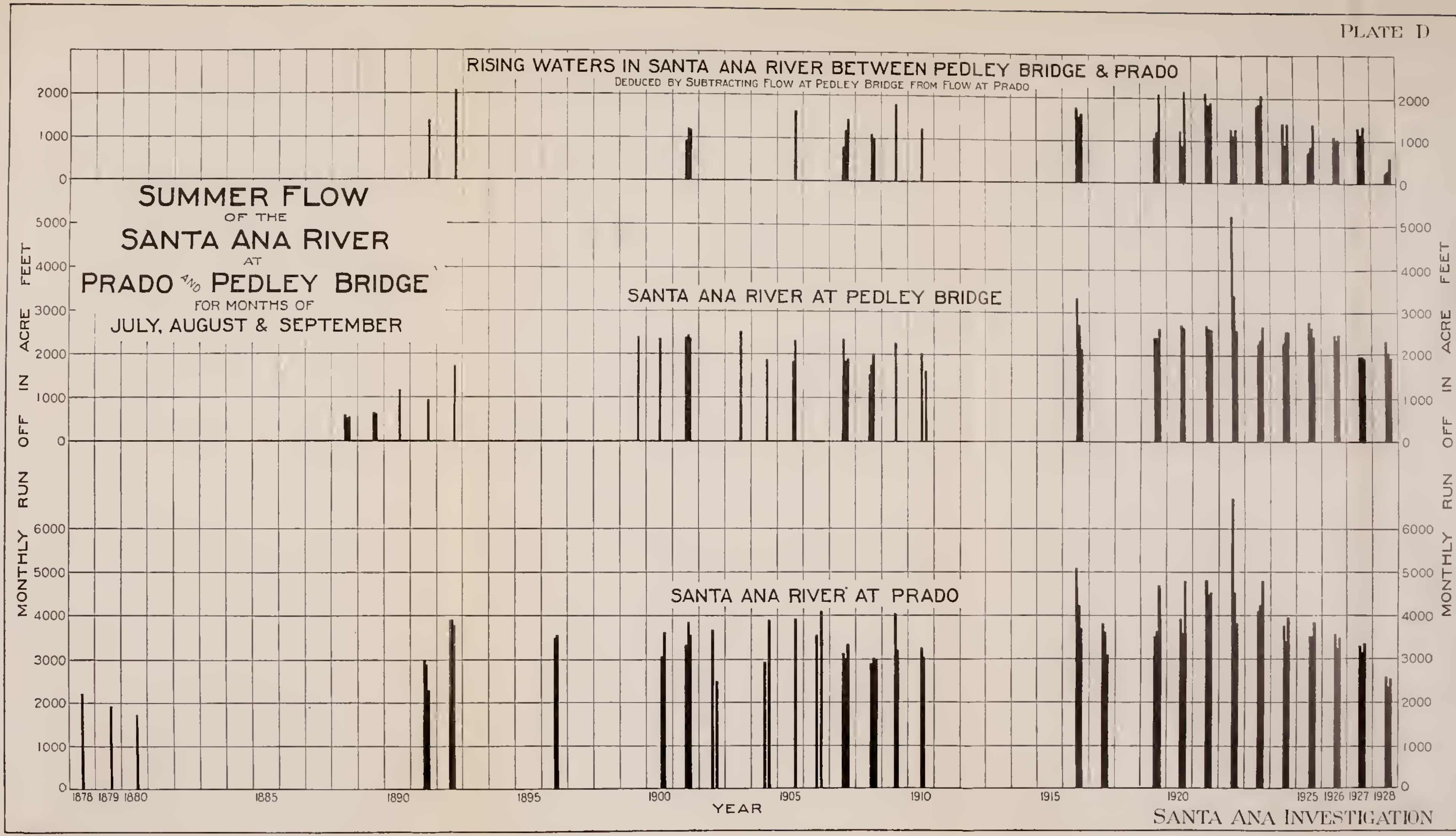


PLATE D
RISING WATERS IN SANTA ANA RIVER BETWEEN PEDLEY BRIDGE & PRADO
DEDUCED BY SUBTRACTING FLOW AT PEDLEY BRIDGE FROM FLOW AT PRADO
SUMMER FLOW
OF THE
SANTA ANA RIVER
AT
PRADO AND PEDLEY BRIDGE
FOR MONTHS OF
JULY, AUGUST & SEPTEMBER
SANTA ANA RIVER AT PEDLEY BRIDGE
SANTA ANA RIVER AT PRADO
MONTHLY RUN OFF IN ACRE FEET
YEAR
1878 1879 1880 1885 1890 1895 1900 1905 1910 1915 1920 1925 1926 1927 1928
SANTA ANA INVESTIGATION
63685

Works. The results of observations in 1927 are shown on map 8, in pocket, "Elevation of Ground Water in Recent Gravels," and map 9, in pocket, "Depth of Ground Water in Recent Gravels."

The lowering water plane is a matter of common statement. A permanent lowering water plane is inherent in the complete use of underground waters. In such a wet year as 1916 recharge takes place, and the intermediate extraction and lowering is an incident of the utilization of 1,500,000 acre-feet of gravel storage. A maximum development requires large lowering of the water plane during the dry period and a corresponding recharge during the wet period of a complete cycle.

The permanent lowering of the water plane underlying moist areas is a requisite for the salvage of evapo-transpiration losses. The observed decrease in artesian area represents salvage.

Complete comparison of the water plane in different years for all the gravels in the watershed is not possible for several reasons. Some of the gravels contain no wells; in others, wells have been installed recently, but not in the earlier years. In order to reach general conclusions, as wide an area as possible should be examined rather than individual wells, and the period of years should be large.

For an answer as to the long period, the situation compiled by Mendenhall in the year 1904 as given in U. S. Geological Survey water supply papers, is compared with the observations by this investigation in 1927. The results are shown in Table A, page 43, and the area covered is shown in Plate E, facing page 42. The area compared is the area shown by Mendenhall, amounting to 352 square miles, or 41 per cent of the total gravel area. On 239 square miles the hydrographic contours are compared and the volume of change is estimated. On 123 square miles of artesian area, shrinkage alone is shown. No general conclusion can be drawn as to the balance of the gravel area.

Table A shows that on 100 square miles in Lower Basin the total decrease is 33 feet in the 24 years; in Cucamonga Basin the decrease on 95 square miles has been 45 feet, and on 5 other square miles the increase has been 31 feet; in Jurupa Basin the decrease on 11 square miles has been 48 feet and on 10 other square miles the increase has been 36 feet; in Upper Basin the decrease on 3 square miles has been 100 feet, and on 35 other square miles the increase has been 26 feet. In the artesian area not included in these figures, Lower Basin has decreased 88 square miles in area; Cucamonga Basin 15 square miles and Upper Basin 3 square miles.

If the percentage of voids is assumed to be 15 per cent the volume of the decrease in Lower Basin is estimated at 313,000 acre-feet. In Cucamonga Basin the decrease was 410,000 acre-feet on one portion and the increase on another portion was 15,000 acre-feet, a net decrease of 395,000 acre-feet. In Jurupa Basin the decrease was 53,000 acre-feet on one portion and the increase on another portion was 34,000 acre-feet, a net decrease of 19,000 acre-feet. In Upper Basin the decrease was 32,000 acre-feet on one portion, and the increase on another portion was 86,000 acre-feet, a net increase of 54,000 acre-feet. The total decrease confined to 28 per cent of the gravel area is 673,000 acre-feet. This is exclusive of effects within the additional 13 per cent of former artesian area.

The year 1904 was in the preceding dry cycle. By 1916 general recharge occurred. Table A might be interpreted as showing that the

Works. The results of observations in 1927 are shown on map 8, in pocket, "Elevation of Ground Water in Recent Gravels," and map 9, in pocket, "Depth of Ground Water in Recent Gravels."

The lowering water plane is a matter of common statement. A permanent lowering water plane is inherent in the complete use of underground waters. In such a wet year as 1916 recharge takes place, and the intermediate extraction and lowering is an incident of the utilization of 1,500,000 acre-feet of gravel storage. A maximum development requires large lowering of the water plane during the dry period and a corresponding recharge during the wet period of a complete cycle.

The permanent lowering of the water plane underlying moist areas is a requisite for the salvage of evapo-transpiration losses. The observed decrease in artesian area represents salvage.

Complete comparison of the water plane in different years for all the gravels in the watershed is not possible for several reasons. Some of the gravels contain no wells; in others, wells have been installed recently, but not in the earlier years. In order to reach general conclusions, as wide an area as possible should be examined rather than individual wells, and the period of years should be large.

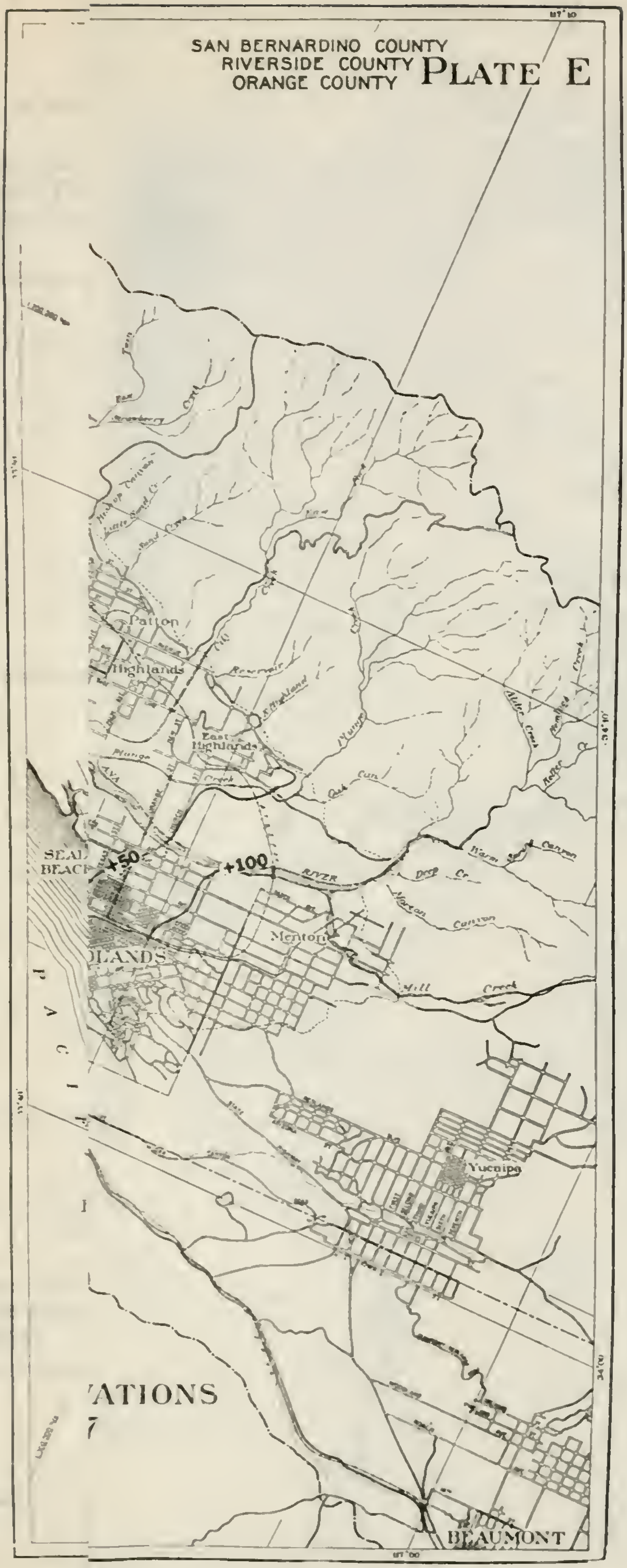
For an answer as to the long period, the situation compiled by Mendenhall in the year 1904 as given in U. S. Geological Survey water supply papers, is compared with the observations by this investigation in 1927. The results are shown in Table A, page 43, and the area covered is shown in Plate E, facing page 42. The area compared is the area shown by Mendenhall, amounting to 352 square miles, or 41 per cent of the total gravel area. On 239 square miles the hydrographic contours are compared and the volume of change is estimated. On 123 square miles of artesian area, shrinkage alone is shown. No general conclusion can be drawn as to the balance of the gravel area.

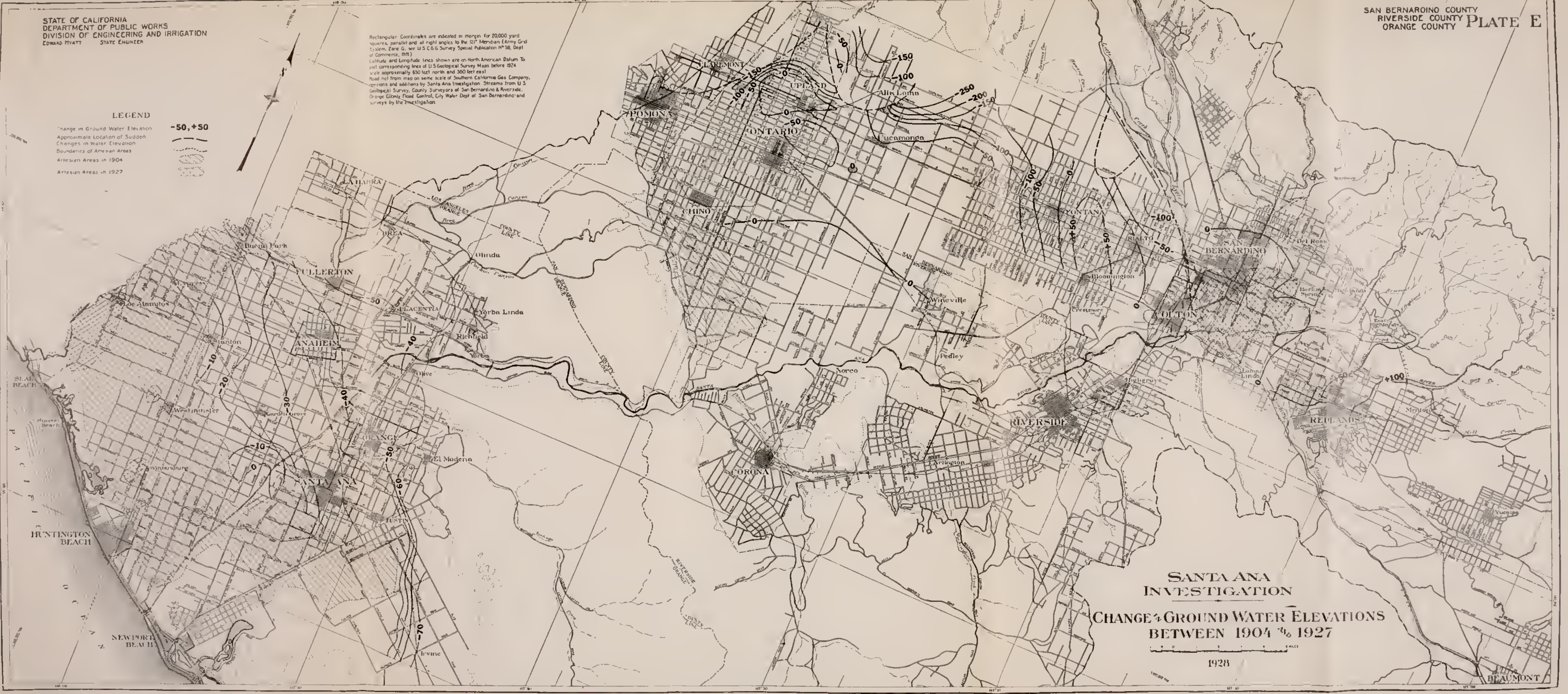
Table A shows that on 100 square miles in Lower Basin the total decrease is 33 feet in the 24 years; in Cucamonga Basin the decrease on 95 square miles has been 45 feet, and on 5 other square miles the increase has been 31 feet; in Jurupa Basin the decrease on 11 square miles has been 48 feet and on 10 other square miles the increase has been 36 feet; in Upper Basin the decrease on 3 square miles has been 100 feet, and on 35 other square miles the increase has been 26 feet. In the artesian area not included in these figures, Lower Basin has decreased 88 square miles in area; Cucamonga Basin 15 square miles and Upper Basin 3 square miles.

If the percentage of voids is assumed to be 15 per cent the volume of the decrease in Lower Basin is estimated at 313,000 acre-feet. In Cucamonga Basin the decrease was 410,000 acre-feet on one portion and the increase on another portion was 15,000 acre-feet, a net decrease of 395,000 acre-feet. In Jurupa Basin the decrease was 53,000 acre-feet on one portion and the increase on another portion was 34,000 acre-feet, a net decrease of 19,000 acre-feet. In Upper Basin the decrease was 32,000 acre-feet on one portion, and the increase on another portion was 86,000 acre-feet, a net increase of 54,000 acre-feet. The total decrease confined to 28 per cent of the gravel area is 673,000 acre-feet. This is exclusive of effects within the additional 13 per cent of former artesian area.

The year 1904 was in the preceding dry cycle. By 1916 general recharge occurred. Table A might be interpreted as showing that the pumping down necessary for the state of development in 1927, is greater than the pumping down necessary for the development as it was in 1904. Whenever the observations shall have been made on a future recharge, it will be possible to determine over a much larger area, whether the present lowering is necessary and incidental to the economic use of gravel storage, or whether the ground water platform has been depressed unduly by removal of basic water which is capital, and should not be used in the ordinary course of business.

It is generally accepted that certain subbasins are overdrawn; that is, the average pumping draft exceeds the average supply. Other subbasins are showing satisfactory storage conditions without notable change of the ground water platform, frequently due to active spreading. As to the entire gravel area as a whole, it would appear that its draft is not well distributed and that it is overdrawn. This is based on the consideration of the actual and large decrease in 24 years and the estimated consumptive use of today, considerably in excess of the supply.


SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
PLATE E
Patton
Highlands
East Highlands
SEAL BEACH
+50
+100
Mentone
LANDS
Yucaipa
BEAUMONT
ATIONS
Mill Creek
Warm Springs Canyon
Oak Glen
Morton Canyon



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT STATE ENGINEER
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
PLATE E
Rectangular Coordinates are indicated in margin for 20,000 yard squares, parallel and at right angles to the 121° Meridian (Army Grid System, Zone G, see U.S.C.&G. Survey Special Publication No. 59, Dept of Commerce, 1918)
Latitude and Longitude lines shown are on North American Datum. To plot corresponding lines of U.S. Geological Survey Maps before 1924 scale approximately 650 feet north and 300 feet east
Road net from map on same scale of Southern California Gas Company, revisions and additions by Santa Ana Investigation. Streams from U.S. Geological Survey, County Surveyors of San Bernardino & Riverside, Orange County Flood Control, City Water Dept of San Bernardino and surveys by the Investigation
LEGEND
Change in Ground Water Elevation -50, +50
Approximate Location of Sudden Changes in Water Elevation
Boundaries of Artesian Areas
Artesian Areas in 1904
Artesian Areas in 1927
SANTA ANA INVESTIGATION
CHANGE IN GROUND WATER ELEVATIONS BETWEEN 1904 TO 1927
1928
POMONA
CLAREMONT
UPLAND
ONTARIO
Cucamonga
Alta Loma
CHINO
FONTANA
RIALTO
SAN BERNARDINO
COLTON
REDLANDS
RIVERSIDE
CORONA
Arlington
Norco
Pedley
Wineville
Bloomington
LA HABRA
BREA
FULLERTON
PLACENTIA
Yorba Linda
Richfield
Olinda
ANAHEIM
ORANGE
SANTA ANA
El Modena
Tustin
Irvine
Westminster
Garden Grove
Buena Park
Los Alamitos
HUNTINGTON BEACH
NEWPORT BEACH
SEAL BEACH
BEAUMONT
Yucaipa
Mentone
Del Rosa

63685

TABLE A

Change in water table in portions of valley floor of Santa Ana watershed between 1904 and 1927

Based on hydrographic contours shown on Plate I of U. S. Geological Survey Water Supply Paper 138, compared with similar contours on Map 8 (in pocket) of Santa Ana Investigation. The result is delineated on Plate E, facing page 42.

LOWER BASIN

Number of square miles compared	Total decrease for period		Number of square miles compared	Total increase for period	
	Contours of Plate E	Average feet		Contours of Plate E	Average feet
2.3	0	0	0	0	0
4.6	0–10	5			
9.7	10–20	15			
15.0	20–30	25			
40.5	30–40	35			
23.1	40–50	45			
2.9	50–60	55			
1.7	60–70	65			
99.8	Weighted mean	33	0	Weighted mean	0

CUCAMONGA BASIN

4.5	0	0	3.9	0–50	25
58.6	0– 50	25	1.2	50	50
3.3	50	50			
15.8	50–100	75			
10.6	100–150	125			
0.9	150–200	175			
0.9	200–250	225			
94.6	Weighted mean	45	5.1	Weighted mean	31

JURUPA BASIN

6.8	0– 50	25	5.6	0–50	25
3.7	50–100	75	4.2	50	50
1.0	100	100			
11.5	Weighted mean	48	9.8	Weighted mean	36

UPPER BASIN

3.3	100	100	8.8	0	0
			20.9	0– 50	25
			4.3	50–100	75
			0.7	100	100
3.3	Weighted mean	100	34.7	Weighted mean	26

Decrease in artesian area in Santa Ana watershed between 1904 and 1927

Based on the same Plate of U. S. Geological Survey as the preceding, and Map 8 (in pocket).

	Area in square miles 1904	Area in square miles 1927
Upper Basin	13.2	10.4
Cucamonga Basin	14.8	0 0
Lower Basin	95.5	7.3
Total	123.5	17.7

TABLE A

Change in water table in portions of valley floor of Santa Ana watershed between 1904 and 1927

Based on hydrographic contours shown on Plate I of U. S. Geological Survey Water Supply Paper 138, compared with similar contours on Map S (in pocket) of Santa Ana Investigation. The result is delineated on Plate E, facing page 42.

Lower Basin

Number of square miles compared	Total decrease for period: Contours of Plate E	Total decrease for period: Average feet	Number of square miles compared	Total increase for period: Contours of Plate E	Total increase for period: Average feet
2.3	0	0	0	0	0
4.6	0–10	5			
9.7	10–20	15			
15.0	20–30	25			
40.5	30–40	35			
23.1	40–50	45			
2.9	50–60	55			
1.7	60–70	65			
99.8	Weighted mean	33	0	Weighted mean	0

Cucamonga Basin

4.5	0	0	3.9	0–50	25
58.6	0– 50	25	1.2	50	50
3.3	50	50			
15.8	50–100	75			
10.6	100–150	125			
0.9	150–200	175			
0.9	200–250	225			
94.6	Weighted mean	45	5.1	Weighted mean	31

Jurupa Basin

6.8	0– 50	25	5.6	0–50	25
3.7	50–100	75	4.2	50	50
1.0	100	100			
11.5	Weighted mean	48	9.8	Weighted mean	36

Upper Basin

3.3	100	100	8.8	0	0
			20.9	0– 50	25
			4.3	50–100	75
			0.7	100	100
3.3	Weighted mean	100	34.7	Weighted mean	26

Decrease in artesian area in Santa Ana watershed between 1904 and 1927

Based on the same Plate of U. S. Geological Survey as the preceding, and Map S (in pocket).

	Area in square miles 1904	Area in square miles 1927
Upper Basin	13.2	10.4
Cucamonga Basin	14.8	0.0
Lower Basin	95.5	7.3
Total	123.5	17.7

The Waste as of Today.

The principal field of conservation in the Santa Ana watershed is the conservation of flood waters now escaping into the ocean and retaining them in situations where the water will be available in dry years.

The storm waters escaping into the ocean during the last 15 years are estimated to average 45,000 acre-feet annually. Over a 34-year period the average waste is somewhat less, probably 33,000 acre-feet. In either period, the maximum waste in any one year, 1915-16, was 286,000 acre-feet. In order to completely regulate the waste flood waters, requires then storage of approximately 286,000 acre-feet, in order to equalize and secure an average additional supply of 33,000 acre-feet.

The estimated annual wastes are shown in Table B, page 45. This table shows for the maximum year, to secure complete storm water conservation, that storage of 143,000 acre-feet is required in Upper Basin or below; 24,000 acre-feet in Jurupa Basin; 18,000 acre-feet in Cucamonga Basin; 48,000 acre-feet in Temescal Basin; and 53,500 acre-feet on Santiago Creek in the Lower Basin.

If these storage capacities were obtainable in each basin of origin, the result would be a safe yield or annual draft for Upper Basin of 14,000 acre-feet, for Jurupa Basin 3,000 acre-feet, for Cucamonga Basin 3,000 acre-feet, Temescal Basin 6,000 acre-feet, and Lower Basin 7,000 acre-feet; a total of 33,000 acre-feet.

In addition, there are escaping along the ocean front from the Lower Basin, the waters of drainage ditches amounting to about 9,000 acre-feet, which presumably may be salvaged by pumping inland, but requiring some storage for full conservation.

In addition, the escape by underflow from the Lower Basin into the ocean, estimated at 8,000 acre-feet may be salvaged by pumping. This makes 17,000 acre-feet recoverable in Lower Basin, independently of basins above. The remaining escape, 5,000 acre-feet estimated run-off from storms in the local area, is not considered as recoverable.

Thus the total waste is estimated at 55,000 acre-feet, and the portion recoverable is estimated at 50,000 acre-feet.

TABLE B

Escape into ocean

Segregated into basins of origin

Only during storm period is water carried directly into the ocean from basins of origin. Under the "Miscellaneous Escapes from Lower Basin" is shown that portion which discharges continuously, irrespective of storms, the immediate source being the lower basin, although part of the water may have originated above, and sunk into the ground-water, finally wasting into the ocean. To Miscellaneous Escapes are added the occasional local storm flow from coastal foothills not draining into the Santa Ana River.

Method of preparing Table. Working backward from the lowest point of drainage, the total escape to the ocean was first analysed and set down. From this was substracted drainage ditches, sewage, underflow and runoff of foothill areas. The remainder is taken as the storm waters originating in mountain areas of Lower basin and mountain and valley areas of upper basins. The only mountain stream in the Lower basin is Santiago Creek. The gaging station on this creek measures only storm water, and this record was used for the known period extended by the ordinary method for unmeasured years. The storm discharge from Temescal basin is the "Escape" as estimated in Part II, Table 37, page 202, less an estimated underflow varying from 2,000 to 10,000 acre-feet per year. The remainder after accounting for Santiago Creek and Temescal basin is the storm discharge of three basins, Upper, Jurupa and Cucamonga. It is assumed that the storm discharge from each of these basins is in proportion to the "Escape" of each as already determined in Table 37, and is so distributed in this table.

Year	From Upper Basin	From Jurupa Basin	From Cucamonga Basin	From Temescal Basin	From Santiago Creek of Lower Basin	Total storm waters	Miscellaneous escapes from Lower Basin return water drainage ditches, sewerage and local storm run-off	Total escape to ocean
1913-14	7,500	1,500	5,000	4,000	7,200	25,200	22,500	47,700
1914-15	15,000	2,000	12,000	15,000	17,000	61,000	24,700	85,700
1915-16	143,000	24,000	18,000	48,000	53,500	286,500	34,500	321,000
1916-17	7,000	1,000	4,000	2,000	3,200	17,200	21,500	38,700
1917-18	12,000	4,000	6,000	4,000	5,200	31,200	21,900	53,100
1918-19	0	0	0	0	0	0	20,500	20,500
1919-20	9,500	1,500	1,000	1,000	4,800	17,800	21,800	39,600
1920-21	1,000	0	0	0	900	1,900	20,800	22,700
1921-22	46,000	8,000	17,000	33,000	30,700	134,700	28,200	162,900
1922-23	1,000	200	800	0	100	2,100	21,400	23,500
1923-24	1,000	200	400	0	30	1,630	20,570	22,200
1924-25	0	0	0	0	0	0	20,700	20,700
1925-26	11,000	2,000	800	0	7,770	21,570	20,830	42,400
1926-27	28,000	5,000	1,300	4,000	28,700	67,000	44,700	111,700
1927-28	1,200	600	200	0	700	2,700	17,500	20,200
15 year mean	18,900	3,300	4,400	7,500	10,600	44,700	24,140	68,800
34 year mean	11,000	3,000	3,000	6,000	7,000	33,000	22,000	55,000

The Natural Losses as of Today.

The direct evaporation in the summer season from river beds and transpiration from willows and grasses adjoining is estimated in Part II, Table 25, page 159, at 15,000 acre-feet annually. Evaporation from moist lands in the artesian areas, and excessively subirrigated areas, varies with the character of the season and is estimated on the average to be 30,000 acre-feet annually. This is a total of 45,000 acre-feet, which may be considered recoverable in one way or another.

In Part II, Table 12, page 103, the total natural losses of all kinds has been determined as 93,000 acre-feet, as distinct from beneficial consumptive use. This determination is made on hydraulic considerations by setting up a bookkeeping balance between ascertained supply and escape. This figure of 93,000 acre-feet of natural losses contains, therefore, the ascertainable losses as well as unaccounted losses.

Thus the total natural losses are estimated to be 93,000 acre-feet, of which 45,000 acre-feet are estimated to be recoverable.

Safe Beneficial Consumptive Use as of Today and Future Safe Beneficial Consumptive Use.

Net safe draft or safe yield is defined as the dependable quantity which can be supplied throughout the driest known cycle of years. Net safe draft is used in hydraulic calculations to arrive at the dependable amount which a system can supply by reservoirs or pumps. On account of the successive basins in the watershed, return waters from the areas irrigated above are again and again reused. The sum of all the drafts would contain duplicated return waters. In order to avoid this difficulty in determining the real requirement of the watershed, attention is confined to consumptive use, and the analogous term safe beneficial consumptive use is adopted, instead of safe draft. It is the draft less return water. Beneficial consumptive use for the entire watershed as of today is estimated at 381,000 acre-feet. In addition natural losses amounting as of today to 93,000 acre-feet also do not reach the ocean as waste.

Assuming the known and estimated historical escape into the ocean and assuming the conditions of use and natural loss as of today, the situation for the 34-year period would have been as shown in the following tabulation:

Estimated Mean Annual Quantities for 34-Year Period Under Present Conditions

		Acre-feet
Water supply of all kinds		446,000
Subtract:		
Natural losses of all kinds	93,000	
Waste	55,000	
		148,000
Water supply, less losses and waste; equivalent to safe beneficial consumptive use		298,000
Consumptive use as of today		381,000
Resulting overdraft on ground water		83,000

This tabulation shows on the above assumptions that the safe beneficial consumptive use is 298,000 acre-feet, and that the present consumptive use would have produced, if it had existed during the period, an average annual overdraft of 83,000 acre-feet from the ground water, or in other words ground water storage would have been subject to deficiencies amounting to 22 per cent on the average throughout the period.

Making the same assumptions but limiting them to the period of the last 15 years the situation would have been as follows:

Estimated Mean Annual Quantities for 15-Year Period, Under Present Conditions

		Acre-feet
Water supply of all kinds		543,000
Subtract:		
Natural losses of all kinds	93,000	
Waste into ocean	69,000	
		162,000
Water supply, less losses and waste		381,000
Consumptive use as of today		381,000
Overdraft on ground water		0

That is to say, on the assumptions made, the present consumptive use during the past 15 years would not have shown an overdraft for that period. Comparing the preceeding tabulation this would indicate that the preceeding 19-year period would have contained deficiencies due to such attempted use, amounting to an average during this 19 years of 31 per cent.

The maximum conservation indicated in this report is 50,000 acre-feet consisting of the storm waste of the Santa Ana River, and certain drainage ditches and underflow discharging into the ocean, together with 45,000 acre-feet of natural evaporation losses in channels and moist areas, a total of 95,000 acre-feet annually.

Estimated Mean Annual Quantities for 34-Year Period, Under Future Conditions of Maximum Conservation:

		Acre-feet
Water supply of all kinds		446,000
Subtract:		
Natural losses as reduced by future conservation	48,000	
Waste as reduced by future storage	5,000	
		53,000
Water supply less waste and losses, equivalent to future safe beneficial consumptive use		393,000
Present beneficial consumptive use		381,000
Surplus with present use, and greatest possible conservation		12,000

This shows, when maximum salvage and conservation is completed that the present beneficial consumptive use would be substantially equal to the safe use.

The Capital Floods as of Today Without Regulation.

Capital flood defined. The maximum flood to be anticipated is here called capital flood. Such a flood may not occur once in 100 years. The capital flood adopted in this report is a flood twice that of January, 1916. On streams for which no record exists for 1916, twice the 1927 storm, or three times the 1922 storm has been used.

Floods. The historic flood records have been reviewed, and using the definition of capital flood previously given, Table C is presented showing the estimated contribution of the principal tributaries to the Santa Ana River and the estimated magnitude of the flood at Colton, Pedley Bridge and Santa Ana. This table shows that the mean capital flood for 24 hours would be at Colton, 62,000 second-feet; at Pedley, 64,000 second-feet; and at Santa Ana, 87,500 second-feet.

It will be understood that there already exists certain natural and artificial regulation which is included in the above values. Bear Valley Reservoir and natural absorptive stream beds are examples.

The values shown are the mean discharge for 24 hours. Instantaneous peak discharges in the mountain area may be two or three times higher. It is not probable that the peak of the various tributaries would reach Colton at the same time. It is concluded that the peak at Colton would not exceed the 24-hour mean by over 30 per cent and that in the lower river from Pedley Bridge to Santa Ana it would not exceed it by more than 20 per cent.

TABLE C

Capital flood under existing conditions, as of 1928, without regulation in second-feet average for 24 hours

Day of flood	Santa Ana above Mentone			Mill Creek above Crafton			Plunge Creek above Highlands		
	Santa Ana at Mentone	Absorption between Mentone and Colton	Net reaching Colton	Mill Creek near Crafton	Absorption between Crafton and Colton	Net reaching Colton	Plunge Creek near Highlands	Absorption between Highlands and Colton	Net reaching Colton
1	1,900	1,000	900	1,800	1,000	800	1,500	100	1,400
2	30,000	4,000	26,000	6,700	900	5,800	3,900	400	3,500
3	4,000	2,000	2,000	2,400	400	2,000	1,200	0	1,200
4	2,000	500	1,500	800	200	600	500	0	500
5	2,000	500	1,500	500	100	400	300	0	300
6	2,000	500	1,500	300	50	250	200	0	200

Day of flood	City Creek above Highlands			Cable, Devils, Waterman and Strawberry	Cajon and Lone Pine above Keenbrook			Lytle above Fontana		
	At Highlands	Absorption between Highlands and Colton	Net reaching Colton	Net reaching Colton	Near Keenbrook	Absorption between Keenbrook and Colton	Net reaching Colton	Near Fontana	Absorption between Fontana and Colton	Net reaching Colton
1	2,600	300	2,300	500	1,400	400	1,000	6,000	1,500	4,500
2	4,800	400	4,400	2,000	3,700	1,400	2,300	9,500	1,500	8,000
3	1,500	200	1,300	800	1,500	500	1,000	2,000	500	1,500
4	800	100	700	300	600	500	100	2,000	500	1,500
5	500	100	400	200	300	300	0	2,000	500	1,500
6	400	100	300	100	200	200	0	1,200	300	900

Day of flood	San Timoteo	Warm Creek and Valley floor
	Net reaching Colton	Net reaching Colton
1	4,400	1,500
2	7,100	3,000
3	500	1,500
4	0	400
5	0	300
6	0	250

TABLE C—Continued

Streams as concentrated at Colton

Day of flood	Santa Ana River	Mill Creek	Plunge Creek	City Creek	Cable, Devils, Strawberry and Waterman Creeks	Cajon and Lone Pine Creeks	Lytle Creek	San Timoteo Creek	Warm Creek and Valley floor	Total at Colton
1	900	800	1,400	2,300	500	1,000	4,500	4,400	1,500	17,300
2	26,000	5,800	3,500	4,400	2,000	2,300	8,000	7,100	3,000	62,000
3	2,000	2,000	1,200	1,300	600	1,000	1,500	500	1,500	11,600
4	1,500	600	500	700	300	100	1,500	0	400	5,600
5	1,500	400	300	400	200	0	1,500	0	300	4,600
6	1,500	250	200	300	100	0	900	0	250	3,500

The River at Pedley Bridge

Day of flood	At Colton	Drainage between Colton and Pedley	Total at Pedley
1	17,300	1,000	18,300
2	62,000	2,000	64,000
3	11,600	1,000	12,600
4	5,600	500	6,100
5	4,600	100	4,700
6	3,500	100	3,600

Streams as concentrated at Santa Ana

Day of flood	Santa Ana River at Pedley	Chino Creek	Temescal Creek	Santiago Creek	Absorption in Channel	Total at Santa Ana
1	18,300	250	2,500	1,200	1,000	21,250
2	64,000	1,500	10,000	14,000	2,000	87,500
3	12,600	800	4,000	2,400	1,000	18,800
4	6,100	300	1,000	600	500	7,500
5	4,700	100	500	550	400	5,450
6	3,000	100	400	500	400	4,200

Capital flood momentary peak discharge in second-feet

	Second-feet
Santa Ana River at Mentone	52,000
Lytle Creek at mouth of canyon	28,000
Santa Ana River at Colton	80,000
Santa Ana River at Prado	86,000
Santa Ana River at Santa Ana	100,000

CHAPTER 4

METHODS OF FLOOD CONTROL AND CONSERVATION

Methods of Flood Control.

Flood control proper may be accomplished by reservoirs, by check dams, by channel improvement, and by natural and artificial spreading.

Reservoirs. The typical flood control reservoir is capable of receiving a maximum peak flood, and a maximum 24-hour flood, and discharging at a lesser rate over a longer period. Its openings are always open, and its function is to be empty in ten or fourteen days after a maximum storm, ready to regulate another. Speaking generally it is the more expensive type of structure.

Check dams. Check dams have been long in use in Europe, and have been used in various ways from minor attempts to stop gullying and soil erosion to the wire-bound rock walls of Southern California and elaborate mining debris dams in central California. In principle the check dam should cause a deposition of transported flood load at and above the structure; it should reduce the velocity and hence the transporting power of the stream by a series of flat sections and waterfalls. It should cause increased natural storage by absorption in deeper stream gravels; it should reduce the "peak" of floods.

Improvement of channels. In principle, improvement and rectification of channels result in narrower cross sections, higher velocities and higher scouring possibility. The method is adapted to channels discharging into the ocean. Elsewhere it may or may not be advisable depending on the results sought for. Much work of this character heretofore built is a protection work for a particular tract, and frequently does not appear to take into account the general interest.

If flood control is limited entirely to bank protection from end to end of the Santa Ana watershed, this would constitute the method of channelization. This would imply that all channels would be designed for the peak discharge of capital floods. The channels would be wide and the levees of ample height to be safe for maximum conditions. Debris deposition will occur and provision for annual maintenance and increasing the heights of levees should be included in such a solution.

Terminal flood control surface reservoirs. Another method would consist of bank protection in the upper area and provision of large terminal flood control storage at the point where the flood reaches maximum concentration. This method would provide bank protection for the Santa Ana River above Prado and its tributaries. In the vicinity of Prado would be placed storage sufficient to regulate the concentrated flood waters to a reduced flow for the remainder of the Santa Ana River, which would still require bank protection for a lessened channel.

Works for spreading floods. The torrential floods may be passed over a solid weir in the mouths of the canyons and distributed by multiple channels over the gravel cones. Such works would be on a larger and more substantial scale than existing spreading works designed for conservation. A portion of the flood water would continue in the main channel while the balance would be delayed by the longer and rougher courses provided by spreading works. The subdivision into multiple channels would result in decreasing the transporting power, and the varying rates of flow would reduce the peak of floods when again concentrated in the main channel.

Used with flood control reservoirs in the upper tributaries, this would constitute another combined method, resulting in a lessened flow carried on to terminal reservoirs in the lower areas. The official channels could be lessened as well as the size of the terminal reservoirs.

Auxiliary flood control reservoirs. A further method would consist of supplementing flood control reservoirs and flood spreading works by large auxiliary reservoirs on the valley floor. These reservoirs would preferably not be across major stream channels, and would be of large capacity. They would be connected by large feeders capable of carrying the bulk of flood water from the canyons already regulated somewhat by flood control reservoirs therein and by flood spreading works. Such auxiliary reservoirs would be operated to hold their load during the high water and be released on its subsidence. Such a system would accomplish complete flood control.

Methods of Conservation.

Conservation in general. Conservation implies the storage of water, whether during a portion of one season or over a series of years. Conservation also is accomplished when evaporation losses are salvaged. Conservation of wasted power may be gained incidentally in works of storage and salvage.

The conservation of flood waters wasting into the ocean involves long period over-year storage, because the wet years occur at intervals of from three to seven years. In storing the last 13 per cent of the total water supply available a storage capacity of at least six times the annual regulated amount is required. This is over-year storage proper, and would be obtained either by surface reservoirs or by underground gravel reservoirs from which the required water is pumped as needed. In the surface reservoir the stored waters can be delivered to a particular use. In the underground reservoir the identity of the storm water stored is lost. It is mingled with other water reaching the water plane by absorption or as return waters. It does not remain stationary but advances at a slow rate towards lower points where it eventually may emerge in moist areas at the base of the gravel cone. It is subject to utilization by such wells as may penetrate into the underground reservoir, and the owners of these wells may not participate at all in the storage of flood waters, or even be aware of the sources by which they are benefited. Conservation by surface storage may therefore be adopted by a single water organization and succeed in conveying the stored waters into designated areas; while storage in underground reservoirs, speaking generally, is a benefit to all lands overlying the gravels, and no one can identify the storm water as distinguished from other waters in the reservoir.

Conservation of winter water for use in the summer, or what is known as annual or seasonal regulation is another matter. The storage capacity required for this particular purpose may be from 20 per cent to 40 per cent of the annual requirement for irrigation. It is most obviously accomplished by surface reservoirs, but underground storage is easily adapted to it with the same qualification regarding the identity of the water as in the case of over-year storage.

It is obvious that annual storage might be alternatively accomplished either by surface storage above the lands to be utilized, or by the method of spreading the water in the vicinity of use and thereafter pumping in the summer time. The amount of water used in either case would be the same. The surface reservoir, on one hand, would be subject to evaporation losses. It would, however, salvage the energy of the water which could be made to generate power. In the other method evaporation loss is absent. Some of the waters spread may not be recovered. Power is required to lift all of the water.

Storage in the uppermost gravels presents an analogous situation. The higher storage reduces the pumping lift, irrespective of its destined use. The benefit of successive return waters, which is a notable fact of this watershed, would be increased. For ordinary or minor storms, practically all storm water can be stored in the upper gravels of the watershed. For the occasional extreme storms, storage near sea level may become necessary.

The energy now lost by permitting waters to seek low levels may be recovered in transit by canals substituted for the natural water courses. Where topographic conditions exist for surface reservoirs at the head of such canals, the recovery of power would be more complete. Conservation in this case would combine the recovery of power with the salvage of water now evaporated from broad, sandy streambeds.

Salvage of evaporation from moist areas may be accomplished by drainage and the drainage water pumped to other land and utilized.

Conservation extended to the use of imported waters means in the Santa Ana watershed the use of sewage of the Los Angeles metropolitan area and Colorado River water. Waters of the San Jacinto River, which ends in Lake Elsinore, is already used in that watershed. Only at very infrequent periods does Lake Elsinore overflow. The waters of the Mojave River are generally considered to be unavailable for legal reasons. The other opportunities for drainage capture from outside of the watershed, are few in number. The diversion of Baldwin Lake drainage area into the Bear Valley reservoir is an example, and the diversion of Swartout Canyon water into the head of Lone Pine Creek is another.

Incidental conservation by flood control. To a limited extent certain flood control works, such as flood control reservoirs, check dams and flood spreading contribute to conservation by increasing the period during which storm waters may be absorbed. Such works would also contribute effectively to conservation by furnishing the substantial structures which could serve as intakes for intensive spreading or for conduits leading to economic storage elsewhere in localities favorable for use.

Water spreading. The most economical method of conservation in the Santa Ana watershed is water spreading. It has been shown that

95 per cent of the over-year storage now effective on the watershed is gravel storage. This has been obtained partially by natural conditions, and partially by artificial spreading. To conserve the storm waters now wasting into the ocean requires the absorption of peak floods to a greater extent than accomplished by present dispositions. The combination of a flood control reservoir with ample spreading grounds becomes increasingly necessary. The unused gravel areas of the Santa Ana watershed are ample to furnish this storage. The technique of spreading maximum flood waters is more difficult. Silting and puddling of the spreading grounds is found to occur, and in existing practice the maximum floods are allowed to pass until the water has cleared up.

On sites where flood control reservoirs are not available, it appears necessary to design the spreading works for high velocities. These velocities should be sufficient to cause slight scour under maximum flow, probably six or seven feet per second. To secure this involves the risk of concentration and loss of control. The ideal works appear to consist of a solid weir at right angles to the stream, causing a wide dispersion of the flood, followed at some distance below by a diagonal wall on which are arranged the permanent outlets from which numerous canals and channels can be supplied, and finally a third protective levee at the end of the spreading field to reconduct waste water or rushes due to failure of any portion of the upper works back into the stream.

Such works are probably capable of controlling and spreading one second-foot per linear foot of diagonal wall. It would appear that the amount spread is largely a matter of ample wall length, and of course of sufficient spreading lands below. Future spreading works may have to be designed for 5000 second-feet maximum flow.

Although spreading has been accomplished for costs as low as twenty cents per acre-foot for the spreading operation alone, strictly the cost of pumping from the gravels should be considered in comparing with costs of surface storage. It emphasizes the importance of spreading in such localities as facilitate pumping.

Surface reservoirs. Reconnaissance has developed several types of reservoirs in the Santa Ana watershed. The mountain sites are not numerous, rather costly and of small capacity. None are as favorable as the existing Bear Valley reservoir. Within the valley floor and foothills, numerous sites exist, of more reasonable cost and of large capacity. In very few instances would their construction appear to be economic for over-year storage in themselves. Their obvious utility would consist in storage sufficient to completely supply spreading works and so contribute indirectly to over-year storage. In addition they would serve for annual regulation.

A group of sites exist off the main drainage lines which would permit the threefold function of storage, direct infiltration into the gravels through their porous floors and flood control reservoirs for long period spreading in their vicinity. Such reservoirs are of importance because of their large capacity, safety from destruction and strategic positions above gravel areas favorable for extraction. The Devil's Gate Reservoir near Pasadena, while not entirely analogous, illustrates this type. While the dam itself is founded on granite in this case, the floor of the reservoir basin is porous gravel. Flood water need not be discharged by waste gates, but is absorbed, joins the ground water and is conserved. Such action can be obtained on the Santa Ana watershed to even a greater extent.

Conservation of energy. Storage in surface reservoirs makes possible the use of power below the site. In the mountains not only the fall due to the dam height is available but often the fall from the base of the dam to the first point of irrigation use. In that portion of the Santa Ana River where perennial flow exists, power may be developed to the extent of the flow without the aid of storage.

Salvage of evaporated water. Diverting the water from the natural channel and conducting it by canals alongside would result in salvage of losses by useless evaporation and transpiration in the river bed. Such a canal may be also utilized for power or as a feeder to a reservoir.

CHAPTER 5

NARRATIVE OF UNIT PROJECTS INVESTIGATED

(Refer to Maps 12 and 13, in pocket)

In the course of this investigation a large number of reservoir sites have been examined. In the last few months, the hydraulic elements have been thoroughly developed, so that it is possible to estimate the relation of water supply, reservoir capacity, and economic results. In the following narrative are assembled the projects investigated, with a brief outline of the salient features, whether favorable or unfavorable. In later sections of the report, certain of these investigated projects are selected in various combinations.

1. **Official channels, rights of way.** In any plan, official channels, under public easement or ownership, are required to prevent encroachment upon waterways, for systematic planning of bridges and roads, and to properly locate protection levees and training works. Whatever may be done eventually above for flood reduction, the official channel should be maintained in the meantime, for a capital flood, and paradoxically it should be maintained in ample widths thereafter to provide for underestimate and accident to a particular work above. These channels should be selected with due regard to intakes for spreading grounds and the conservation of water. The channels must provide for debris, and their banks or levees designed for accumulation of debris. The peak flood carrying capacity and the widths suggested are as follows:

Santa Ana River:	*Capacity, second-feet*	*Width, feet*	*Acres required*
From Mentone to Riverside Narrows	60,000	1,000	3,150
From Riverside Narrows to Lower Santa Ana Canyon	40,000	800	1,550
From Lower Santa Ana Canyon via existing channel to ocean	5–10,000	----	----
Lytle Creek:			
From mouth of canyon to Colton	25,000	500	840
Cajon Creek	10,000	300	290
San Timoteo Creek	2,000	200	73
Temescal Creek, 4 miles near mouth	5,000	500	195
San Antonio-Chino Creek	1,000	100	240
Cucamonga Creek	500	100	240
Santiago Creek	5,000	200	195
			6,773

The cost of rights of way including relocated channels is estimated at $1,500,000.

2. **Filerea Reservoir site.** See Plate G, page 62. This site is located on the South Fork of the Santa Ana River. The bed rock is granite. At this site a dam 178 feet high would impound 4000 acre-feet and would cost $1,700,000. The cost per acre-foot of storage capacity is $421. While the cost per acre-foot of capacity is as high as at other sites in this vicinity, the probability of debris concentration in this reservoir is less. The Bear Creek Fork of the Santa Ana River is now regulated by the Bear Valley Reservoir. It is very desirable that a

similar, even if smaller, regulation be secured on the South Fork. Filerea appears to be the most favorable site, all things considered, for this purpose.

Its utility would consist in annual regulation providing 4000 acre-feet of summer gravity water. It could act as a regulating reservoir for power. The fall from this site to the junction of Bear Creek is 900 feet.

3. **Slide Lake Reservoir site.** This situation at times is a natural lake due to the debris entering from Slide Creek on the west. It has been suggested that this may be a site for a small reservoir, or for a check dam. The gradient of Bear Creek is high, 5 per cent or 6 per cent. No survey has been made of the site. See illustrations, Figs. 5 and 6, page 117.

4. **Forks Reservoir site.** See Plate II, page 63. This situation has been fully surveyed up to a height of dam of 400 feet. The bed rock is granite. The estimated cost for a dam 315 feet high is $8,000,000, with a capacity of 19,600 acre-feet; or a cost of $407 per acre-foot of storage capacity.

5. **Hemlock and Mentone Reservoir sites.** These two sites are in the main canyon, immediately below Forks site, and are alternative. The Forks is considered the better of the three. Hemlock site with a dam 255 feet high would have a capacity of 12,200 acre-feet at approximately the same cost per acre-foot as Forks site. Mentone site with a dam 310 feet high and a capacity of 25,000 acre-feet is estimated to cost $19,000,000.

6. **Crafton Reservoir site.** Mill Creek is a stream with heavy gradient carrying considerable debris. The most favorable storage appears to be near the mouth of the canyon where the dam site would be founded in sandstone. As an illustration, a dam 305 feet high has been estimated to cost $9,000,000 with a capacity of 16,000 acre-feet; or a cost of $585 per acre-foot of capacity.

7. **Highlands Reservoir site.** This site is located on City Creek. It has been estimated for a dam of 300 feet, a capacity of 6000 acre-feet, at a cost of $3,100,000, or $526 per acre-foot of capacity.

8. **Keenbrook Reservoir site.** This site is located in Cajon Creek at its junction with Lone Pine Creek. It has been estimated for a height of dam of 180 feet, a storage capacity of 16,600 acre-feet and a cost of $5,400,000, or a cost of $325 per acre-foot of capacity. This site is traversed by the Santa Fe Railroad and the cost of relocating the railroad has been included in the estimate. A practical comment on this site is that the water supply of Cajon and Lone Pine creeks is normally inconsiderable, and large storage is unnecessary in ordinary years because these waters are absorbed and retained by the extensive gravel beds immediately below this reservoir site. These streams are subject to occasional heavy floods, for which there is ample channel capacity below.

Enclosed within the confines of this site is a small natural lake which can be connected with Lone Pine Creek. It affords an opportunity for minor flood control of 200 acre-feet at slight expense.

9. **Reservoir sites on Lytle Creek.** Three reservoir sites are found on Lytle Creek, namely: Hot Springs, Turk Basin No. 2, and Turk Basin No. 1. In addition, on a side canyon entering from the east is the Myer Reservoir site. The depth of granite bedrock for the three sites on Lytle Creek is 100 feet. The reservoir areas of these sites are overlapping, and the estimate made for Turk Basin No. 1 is typical of the other two. As an example Turk Basin No. 1 has been estimated for a rock fill dam 268 feet high, with a capacity of 22,700 acre-feet, at a cost of $7,700,000. This is a cost of $340 per acre-foot of capacity. It is possible to tunnel from Turk Basin Reservoir site and discharge the water into Myer Reservoir site. See Plate J, page 65. A combination of a low diversion weir at Turk Basin site with this tunnel, and Myer Reservoir site gives a total cost of $2,395,000. The result attained would be the reduction of a capital flood peak from 28,000 to 22,000 second-feet, and a reduction of 24-hour capital discharge from 9500 second-feet to 2000 second-feet. In this solution 20,500 second-feet peak discharge will still occur at Colton and provision for such amount of flood would have to be made through the eastern portion of city of Colton.

A more complete regulation would be accomplished by the construction of a 155-foot dam at Turk Basin site instead of the 25-foot weir. See Plate I, page 64. This would store 5000 acre-feet, and produce a complete regulation from 28,000 second-feet peak discharge to 5000 second-feet maximum at any time. This reservoir would cost approximately $4,000,000. In considering the advisability, irrespective of cost, the debris accumulation in Turk Basin must be considered. The probable rate of decrease of capacity due to debris is not determined. The only observations available, those at Devil's Gate Reservoir, show three-tenths of one per cent of the total water transported is debris. For the mean discharge of Lytle Creek, 27,000 acre-feet, this percentage would indicate a reduction in capacity of 81 acre-feet per year, or a life of 68 years. An addition of 50 feet in height would compensate for this deterioration.

10. **Narrows Reservoir site.** This site is located on Cucamonga Creek and has been estimated for a dam height of 270 feet, with a capacity of 3500 acre-feet, and a cost of $3,000,000, or a cost of $856 per acre-foot of storage capacity.

11. **San Antonio Creek sites.** Two reservoir sites have been surveyed on San Antonio Creek. Ontario Reservoir site is estimated for a dam 250 feet high, with a capacity of 9200 acre-feet, and a cost of $5,300,000, or a cost of $570 per acre-foot of capacity.

11a. **Sierra Reservoir site.** This is located above Ontario Reservoir site, the flow line of which would partly overlap into the Sierra site. The Sierra site has not been estimated but would give approximately the same cost per acre-foot of storage.

12. In the upper San Antonio near Camp Baldy is located the Kelly Lake, formerly used for storage, but understood to be now out of service on account of a court order.

13. West of Camp Baldy is located the Sunset Reservoir site, a natural depression, which with an earth dam 30 feet high would have a capacity of 700 acre-feet. In order to supply this reservoir, a diver-

sion canal one-half mile in length would be required from Bear Canyon, a branch of San Antonio Creek.

Reservoir sites on the valley floor. The sites which have been heretofore described constitute the reservoir sites in the mountains proper, or immediately adjacent to them. The others which are now described are within the valley floor, with the exception of the two Santiago sites in the Santa Ana Mountains.

14. **Yucaipa Reservoir site.** This site is located on Live Oak Creek. See Plate K, page 66. The material of the site is old alluvium, and only an earth dam could be constructed. This site has been estimated for a height of 110 feet, a capacity of 7500 acre-feet, at a cost of $1,500,000, or a cost of $198 per acre-foot of storage capacity.

15. **Singleton Reservoir site.** This situation is on Singleton Creek a branch of San Timeteo Canyon. See Plate L, page 67. It is located in the mesas of the old alluvium and would call for an earth structure. It has been estimated for a height of dam of 80 feet, with a capacity of 5500 acre-feet, at a cost of $1,100,000. This is a cost of $200 per acre-foot of capacity. The full utilization of this site would require diversion of flood waters of Edgar Canyon and other streams in the vicinity of Beaumont.

16. **Little Mountain Reservoir site.** See Plate M, page 68. This site is located on the foothill slopes near the base of the cone of Devil Canyon. The floor of the reservoir and the dam site itself is coarse gravel. It has been estimated for a dam of 50-feet height, capacity of 2600 acre-feet, at a cost of $964,000, or a cost of $370 per acre-foot of storage capacity. For a dam 150 feet high, this site would have a capacity of 72,800 acre-feet. It is physically possible to gather into this reservoir, Cajon, Lone Pine, Cable, Devil, Waterman and Strawberry Creek flood waters. They could be spread in Lytle Creek wash.

17. **Red Hill Reservoir site.** This is a small flood control site near Upland, on Cucamonga Creek. On this creek above this site flood control is already highly developed by the works of the Cucamonga Water Company. This company has constructed a main check dam in the mouth of the canyon, another check dam a mile below it, a diagonal spreading wall, and a diagonal collecting wall. A flood control dam has been estimated for a dam height of 60 feet, a capacity of 1000 acre-feet and a cost of $617,000. See Plate O, page 70. This is a cost per acre-foot of capacity of $617. It would be constructed of earth and founded on old alluvium. The flood waters escaping from the Cucamonga spreading works would be led to this reservoir on the west side of Red Hill. From the reservoir, a flood channel is required to conduct the regulated water into the east channel of Cucamonga Creek.

18. **Declez Reservoir site.** See Plate N, page 69. This site is located on the north flank of the Jurupa hills. Its floor is part of the great gravel cone of Lytle Creek and the Cucamonga mountain front. It is an example of pondage upon a porous material, and would require special consideration as a dam site for underflow beneath it. It has been estimated for a dam of 45 feet, with a capacity of 9,500 acre-feet,

at a cost of $1,100,000, or a cost of $113 per acre-foot of storage capacity. If used for conservation, it could be enlarged to 65,000 acre-feet, when its cost is estimated to be $4,847,000. This reservoir has an unimportant local watershed and would be of service only by bringing waters to it by canals from Lytle Creek or the upper Santa Ana River.

19. **Jurupa Reservoir site.** See Plate P, page 71. This site is located in the vicinity of Riverside. The dam site is in the Riverside Narrows between the Union Pacific Railroad Bridge and Pedley Bridge. At this point the granite outcrops for four miles in a canyon. The area submerged is a broad valley with considerable improvements, and extends to a point one-half mile above Rubidoux Bridge. It would require some changes in the Mission highway, and a relocation of the Union Pacific Railroad, if the higher dam heights are utilized. This reservoir has been estimated for a height of dam of 85 feet, a storage capacity of 65,000 acre-feet, and a cost of $7,300,000. The cost per acre-foot of capacity would be $113.

The elevation of the stream bed at Jurupa dam site is 690 feet above sea. If this site is used as a diversion point, the elevation is such that it is possible to convey flood waters or water for conservation to Chino Reservoir site, described later. The high water line of Chino Reservoir site is 550 feet. The stream bed at Jurupa Reservoir site is 110 feet higher than the high water line of Lower Santiago Reservoir site, described later. It is at the same elevation as the city of Corona.

In the combinations given later, this site is considered entirely as a flood control reservoir without utilization of storage for conservation. It is, however, considered as a head-work for the diversion of waters into Chino Reservoir by a canal on the north side of the river, and it appears to be an appropriate point at which the waters now flowing in the lower channel could be "canalized." This would result in the salvage of waters now subject to natural losses by evaporation and transpiration in the lower river. It would also make possible the rearrangement of irrigation waters now delivered by a longer route to the vicinity of Corona. Such a "canalization" would not take care of all of the waters now flowing in the lower channel, because rising waters occur below this point.

20. **Blue Diamond Reservoir site.** See Plate Q, page 72. This site is on the lower Temescal Creek, where granite bed rock is exposed. The watershed is Temescal Creek below Lake Elsinore, draining the steep eastern slopes of the Santa Ana mountains and lower mesas between Riverside and Perris. It is remotely subject to the overflow of Lake Elsinore. The probability of such overflow is decreasing, due to additional storage works above the lake. The overflow, if it occurs, would not be synchronous with the floods of the local area.

This site has been estimated for a height of dam of 160 feet, a capacity of 81,500 acre-feet, and a cost of $4,081,000. This is a cost per acre-foot of capacity of $50.

Its utility for flood control would be to convert a possible capital flood of 10,000 second-feet to 500 second-feet. For this purpose a capacity of 31,000 acre-feet is sufficient. Its utility for over-year storage and annual storage would be accomplished by extending the

Gage canal to it. The high water level for 81,500 acre-feet would be elevation 900. The Gage canal at Arlington is at elevation 980, or 80 feet higher. Its utility both for over-year storage and annual regulation would be for the Corona region and Orange County canals.

21. **Chino Reservoir site.** This site is located on Chino Creek, five miles south of Chino. The formation is the old alluvium, and would require an earth dam. It is not subject to excessive flood discharges from the Cucamonga Valley. There is a slight perennial flow at the dam site. In extremely high years, it might receive flood waters from the Cucamonga range. Normally, it would have to receive its supply from the Santa Ana River, utilizing the Jurupa dam site as a headworks, and a canal from that point to the reservoir. It has been estimated for a height of dam of 75 feet, a capacity of 39,000 acre-feet, and a cost of $3,200,000 including the canal. This is a cost of $82 per acre-foot of storage capacity. This reservoir would serve, to a certain extent, for over-year storage of waters now escaping into the ocean. Its prime utility would appear to be annual regulation, storing winter water for use at the peak period of irrigation. This would be of service principally to the canal systems of Orange County, and would be an alternative to the Upper Prado and Lower Prado reservoir sites to be described later.

22. **Upper Prado Reservoir site.** Extensive drilling in the lower Santa Ana Canyon and geological investigations have disclosed two sites at which the blue shale is continuous across the canyon. One is the Chester dam site, forming the Upper Prado Reservoir site in the upper portion of the canyon. The other is the Oil Well dam site at the lower end of the canyon near Yorba. The Upper Prado reservoir site has been estimated for a dam height of 93 feet, capacity of 180,000 acre-feet, and a cost of $7.600,000. The cost per acre-foot of capacity is $42. See Plate T, page 74. The foundation is such that an earth dam is required, together with ample provision for flood discharge. The capital peak flood discharge, if no regulation was provided above, is estimated to equal 86,000 second-feet, but with the capacity above given the capital flood can be reduced to 7000 feet below the reservoir and above Santiago Creek.

The above cost estimate and estimate of utility and flood control are from the chief engineer of Orange County Flood Control District. The estimate includes cost of the dam, cost of changes in highway and railroad and cost of right of way. It is stated by the chief engineer of the district that in addition to the above tangible items there is an intangible item due to the reduction in value of certain water rights in Orange County which will be caused by the construction of this reservoir.

23. **Lower Prado Reservoir site.** See Plate U, page 75. This site is also located upon a shale outcrop with a nearly vertical dip, with a width of 300 feet, and parallel bedding of sandstone on either side.

The plan of Orange County Flood Control District as announced by the chief engineer of the district proposes a reservoir of 180,000 acre-feet capacity at the lower site. The dam is to be of hydraulic fill, 155 ft. in height above stream bed with a crest width of 30 ft. Upstream slope 2.75:1. Downstream slope 3:1. The upstream slope is to be faced with riprap and the cutoff wall is to be two rows of steel sheet piling driven to bedrock and grouted between. Outlet gates are to have capacity of 14,000 second-feet. The spillway is to be an overpour tower type resting on bedrock and with conduits leading from it through the dam and also on bedrock. The maximum regulated flow below will be the same as for Upper Prado Reservoir. The estimated cost is $11,800,000.*

24. **Upper Santiago Reservoir site.** This site is on Santiago Creek, draining the west slopes of the Santa Ana mountains. It is located immediately above the lower Santiago site. It has been estimated for a dam height of 137 feet, a capacity of 32,000 acre-feet, and a cost of $2,215,000. This is a cost per acre-foot of capacity of $69. The foundation is sandstone. The utility of this reservoir would be in over-year and annual storage regulating the flow of Santiago Creek.

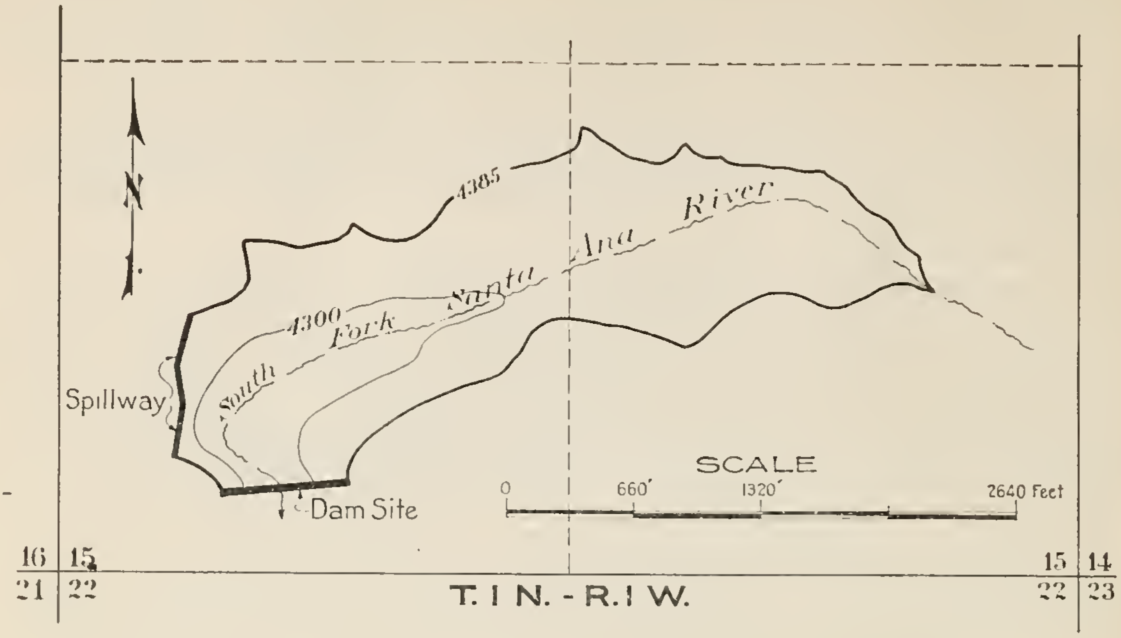
25. **Lower Santiago Reservoir site.** See Plate R, page 73. This site would receive the overflow from Upper Santiago Reservoir. It has been estimated for a dam height of 110 feet, a capacity of 23,600 acre-feet and a cost of $1,188,000. This is a cost per acre-foot of storage capacity of $51. The foundation would be of sandstone. The maximum observed peak flood discharge is 11,000 second-feet. The capital 24-hour flood is taken to be 14,000 second-feet.

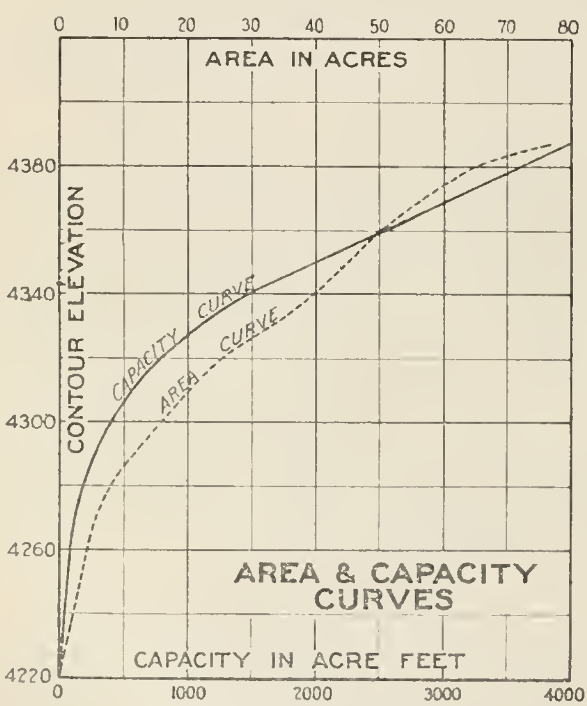
The utility of this reservoir would be to reduce this capital flood from 14,000 second-feet to a regulated flow of 2300 second-feet. This site would have utility also as a conservation reservoir, providing over-year and annual storage of waters wasting from Upper Santiago site, or waters which might be conveyed into it. The high water line is 580 feet above sea. It is, therefore, 110 feet lower than the base of Jurupa Reservoir site, previously described. It is 35 miles distant from the Jurupa site on contour lines. It is, therefore, physically possible to divert water at Jurupa Reservoir and convey it for storage in Lower Santiago Reservoir. This would result in over-year and annual storage of Santa Ana River water for use in Orange County.

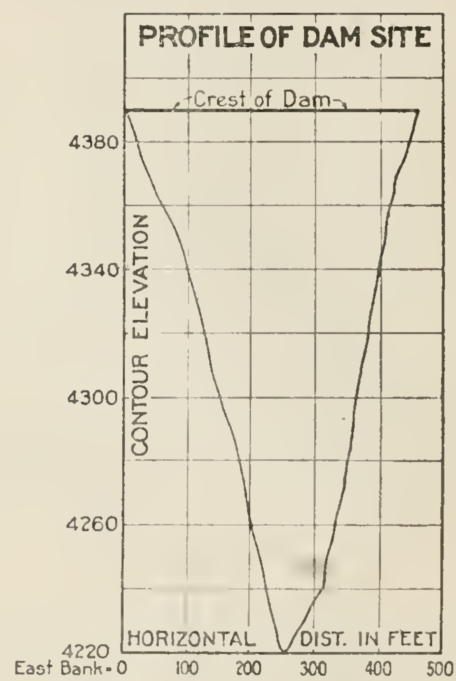
26. **Irvine Reservoir site.** This site is located, within 50 feet of sea level, three miles east of the city of Newport. It is estimated for a height of dam of 40 feet, a storage capacity of 16,800 acre-feet, and a cost of $242,000. This is a cost per acre-foot of storage capacity of $15. The formation at the dam site is clay, and calls for an earth dam. The tributary drainage area is not subject to excessive flood discharge, and no special provision need be made for spillways. This reservoir would be filled by a flood canal from the Santa Ana River which would start from a point near the city of Santa Ana, would have a length of 5 miles, and would be of capacity to accommodate 5000 second-feet. The utility of this reservoir would be over-year storage of the Santa Ana River at its lowest point, practically below all useful diversions, and at a point where the water would otherwise flow into the ocean. It would also serve for the winter storage of water now flowing into the ocean from some 10 drainage ditches between Newport and Bolsa Chica, if they were pumped to the reservoir.

* Report of chief engineer, Orange County Flood Control District.

PLATE G





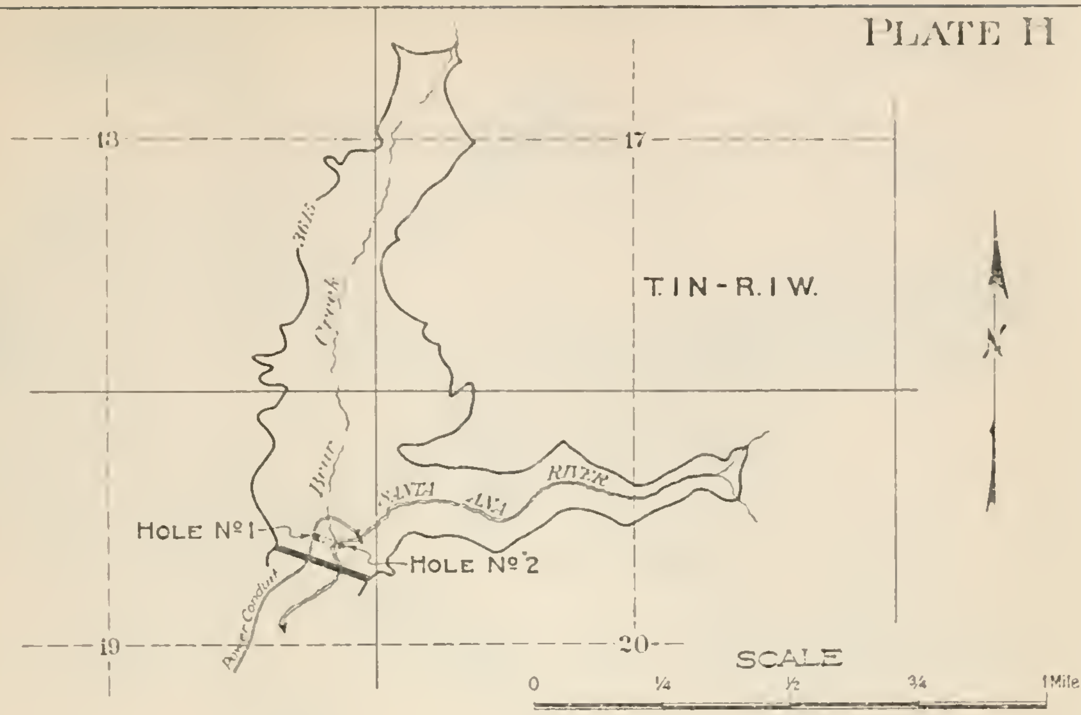


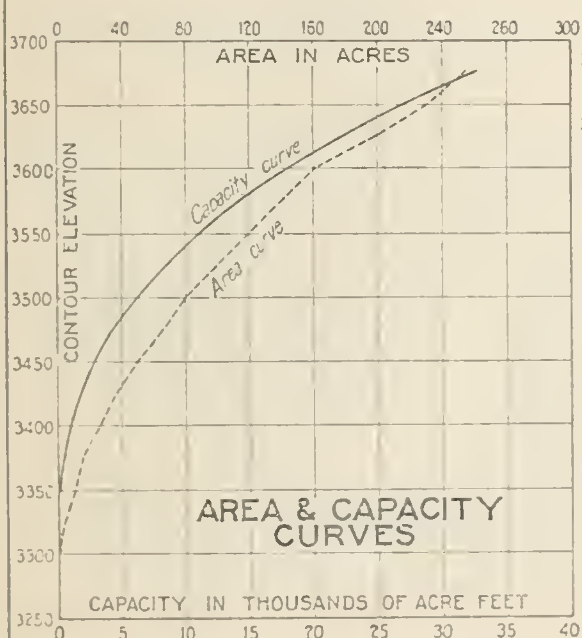
FILREA RESERVOIR SITE

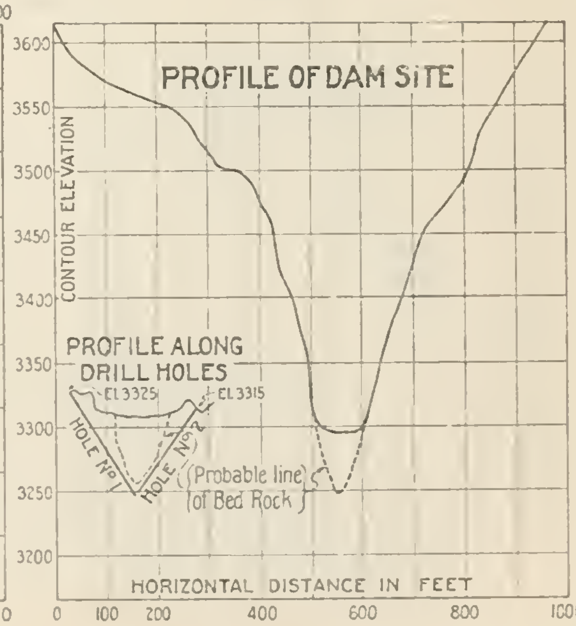
Type of Dam – Gravity Concrete *(See Plate N° 2)*	
Height of Dam	178 Feet
Capacity	4000 Acre Feet
Elevation Stream Bed	4212 Feet
Elevation Crest	4390 Feet
Elevation Spillway	4385 Feet
Width of Crest	20 Feet
Area Reservoir	77 Acres
Estimated Cost	$1,700,000
Cost per Acre Foot of Storage	$421

SANTA ANA INVESTIGATION

PLATE II





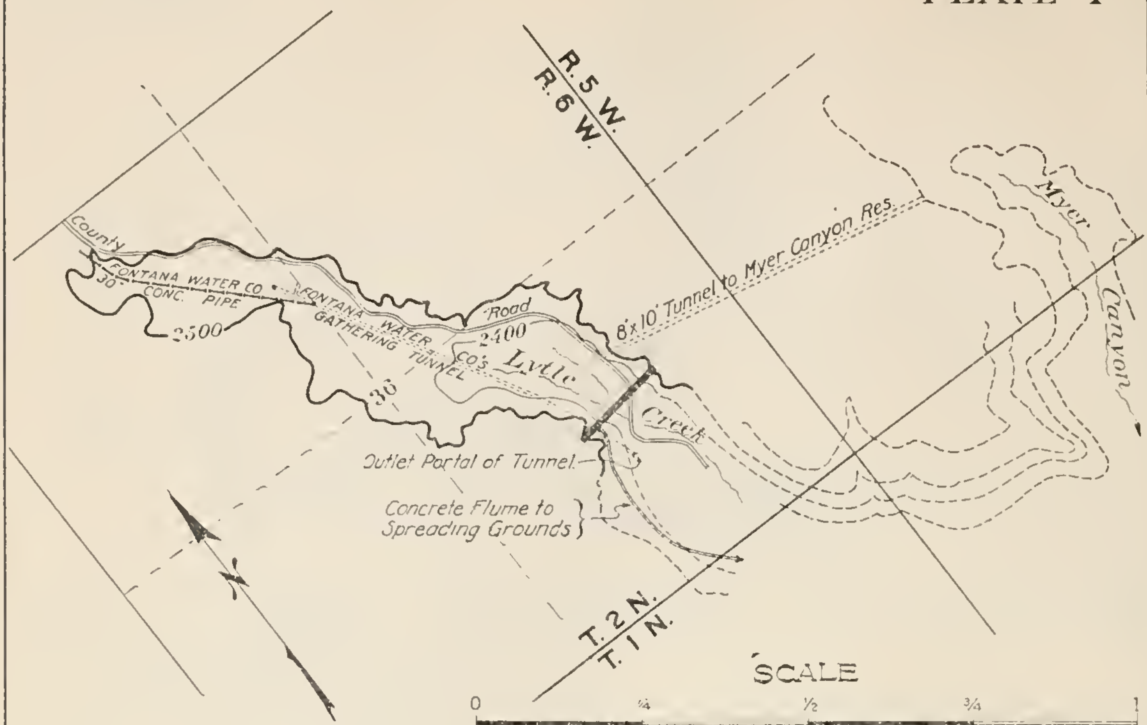


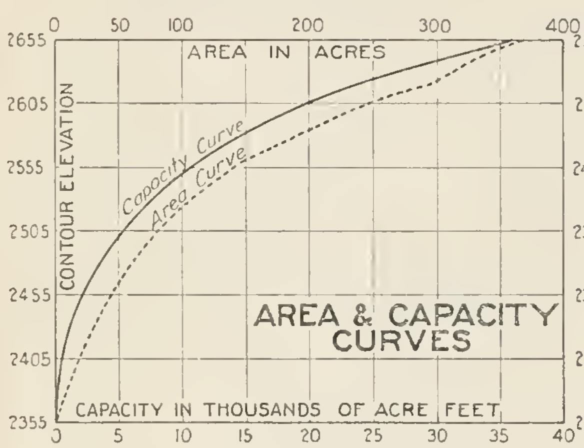
FORKS RESERVOIR SITE

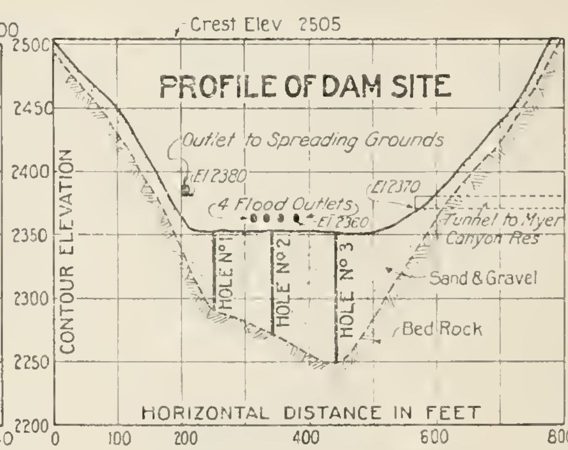
Type of Dam	Gravity Concrete (*See Plate Nº 2*)
Height of Dam	315 Feet
Capacity	19,625 Acre Feet
Elevation Stream Bed	3300 Feet
Elevation of Crest	3615 Feet
Elevation of Spillway	3610 Feet
Width of Crest	20 Feet
Area of Reservoir	168 Acres
Estimated Cost	$ 8,000,000
Cost per Acre Foot of Storage	$407

SANTA ANA INVESTIGATION

PLATE I





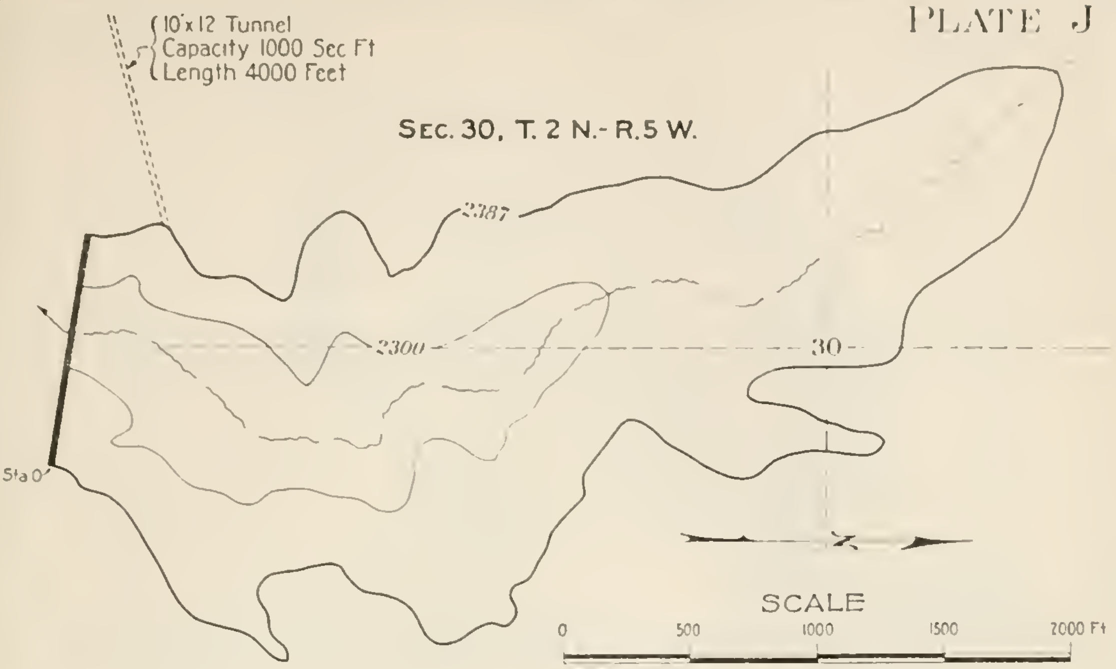


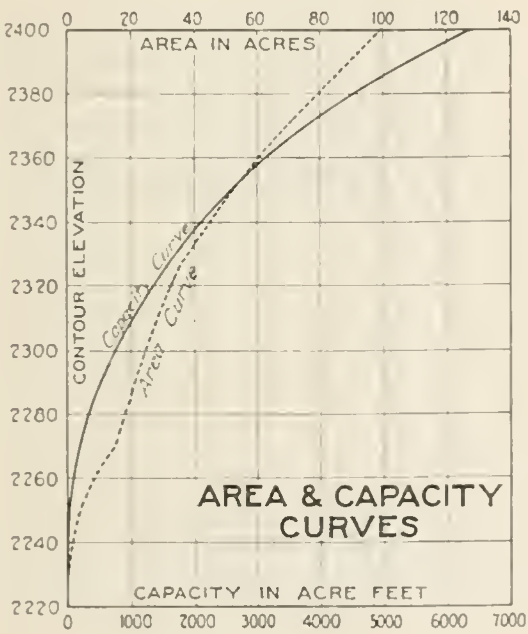
TURK BASIN RESERVOIR SITE

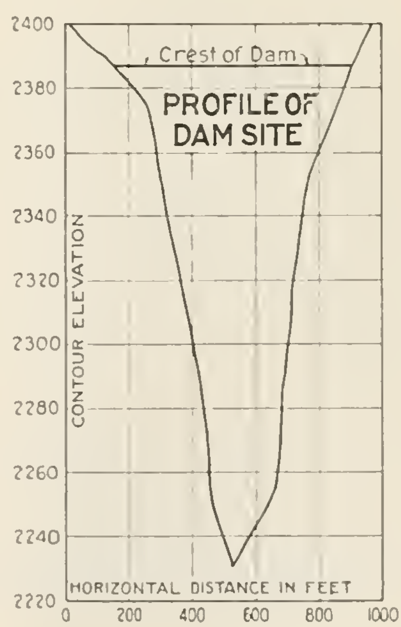
Type of Dam Gravity Concrete	(*See Plate No 2*)
Height of Dam	155 Feet
Capacity	5000 Acre Feet
Elevation of Stream Bed	2350 Feet
Elevation of Crest	2505 Feet
Elevation of Spillway	2503.5 Feet
Width of Crest	20 Feet
Area of Reservoir	80 Acres
Estimated Cost	$3,970,000
Cost per Acre Foot of Storage	$496

SANTA ANA INVESTIGATION

PLATE J





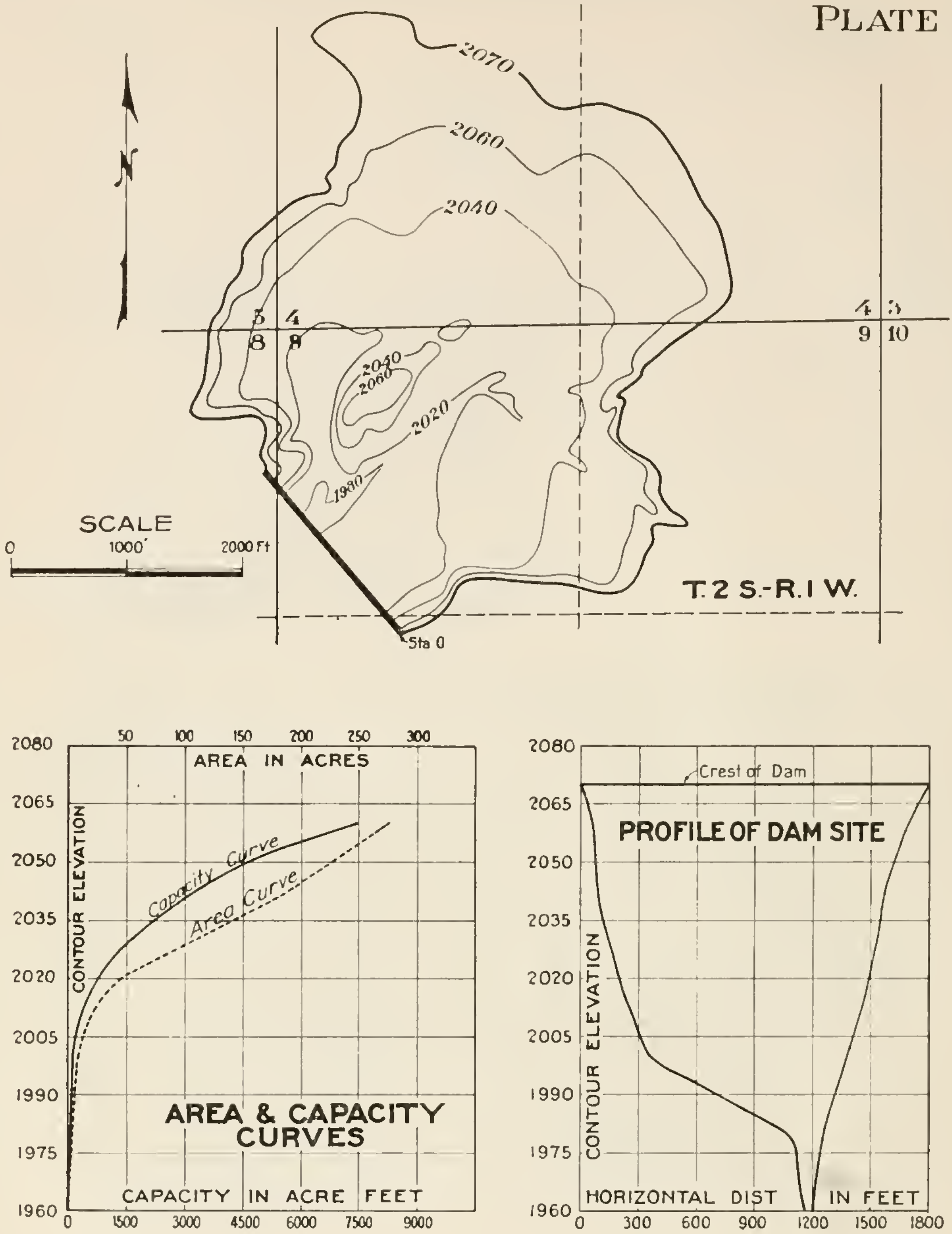


MYER RESERVOIR SITE

Type of Dam - Gravity Concrete		(*See Plate Nº 2*)
Height of Dam		157 Feet
Capacity	5000	Acre Feet
Elevation of Stream Bed		2230 Feet
Elevation of Crest		2387 Feet
Elevation of Spillway		2385 Feet
Width of Crest		20 Feet
Area of Reservoir		90 Acres
Estimated Cost		$ 2,000,000
Cost per Acre Foot of Storage		$ 400

SANTA ANA INVESTIGATION

PLATE K

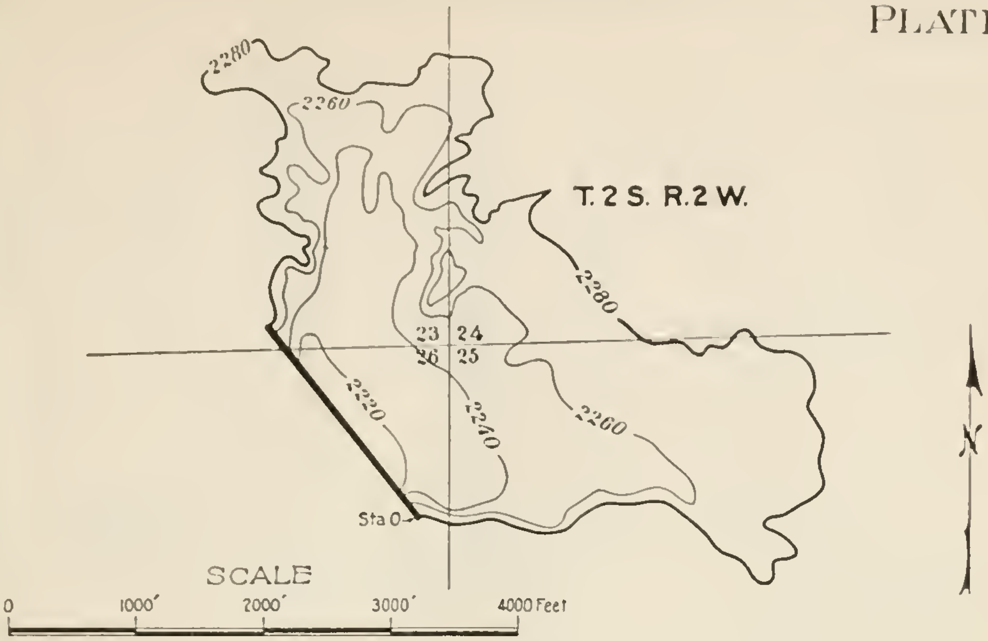


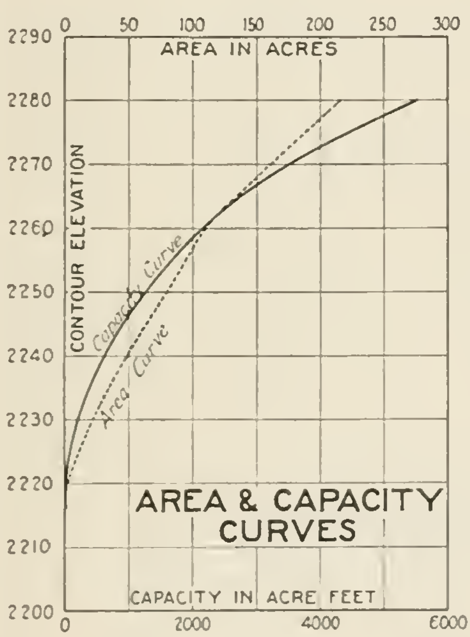
YUCAIPA RESERVOIR SITE

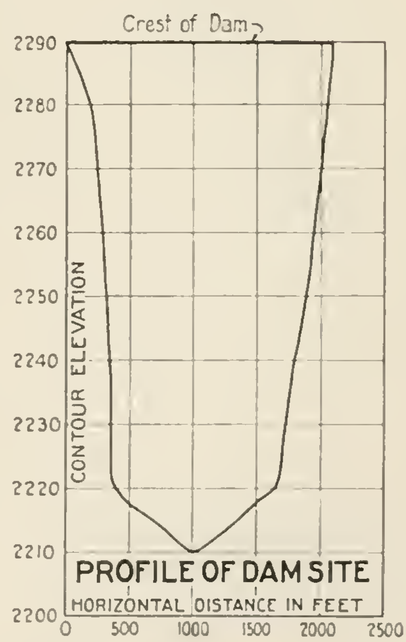
Type of Dam	Earth Fill	*(See Plate Nº 2)*
Height of Dam		110 Feet
Capacity		7500 Acre Feet
Elevation Stream Bed		1960 Feet
Elevation of Crest		2070 Feet
Elevation of Spillway		2060 Feet
Width of Crest		20 Feet
Area of Reservoir		275 Acres
Estimated Cost		$1,480,000
Cost per Acre Foot of Storage		$ 198

SANTA ANA INVESTIGATION

PLATE L





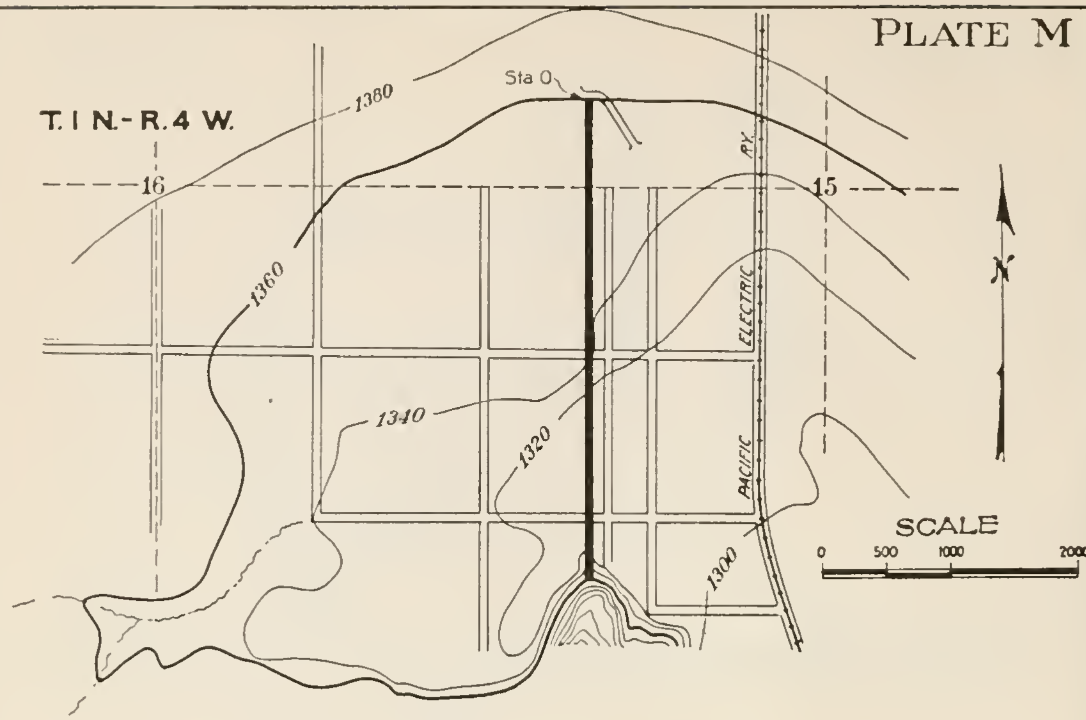


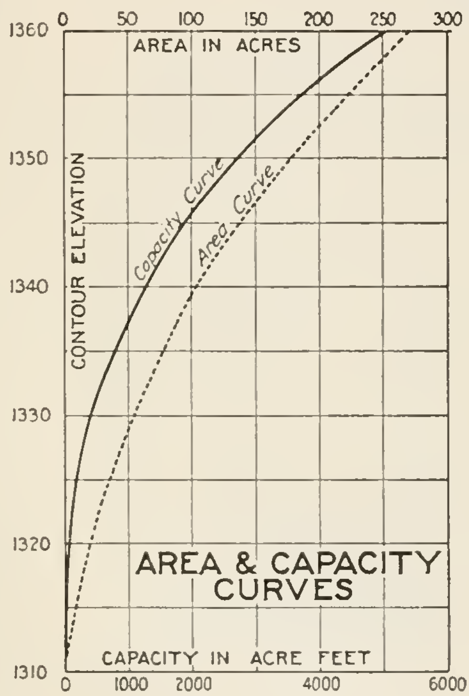
SINGLETON RESERVOIR SITE

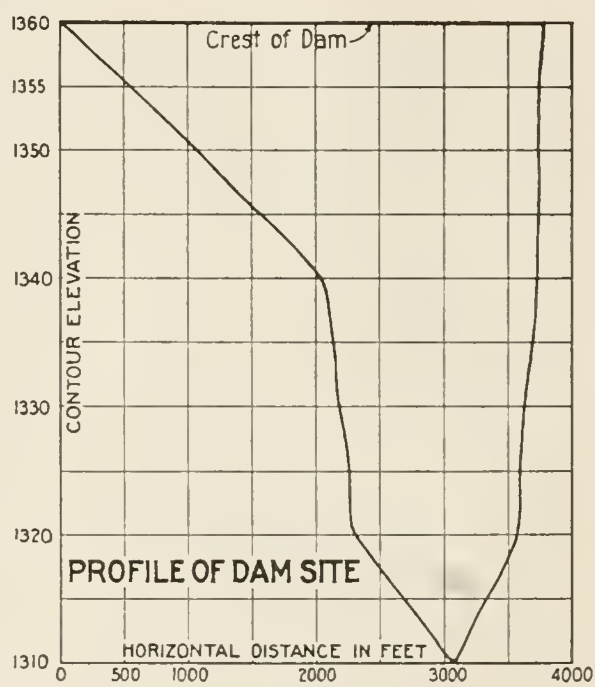
Type of Dam	Earth Fill	*(See Plate No. 2)*
Height of Dam		80 Feet
Capacity	5,500	Acre Feet
Elevation of Stream Bed		2210 Feet
Elevation of Crest		2290 Feet
Elevation of Spillway		2280 Feet
Width of Crest		20 Feet
Area of Reservoir		215 Acres
Estimated Cost		$ 1,098,000
Cost per Acre Foot of Storage		$ 200

SANTA ANA INVESTIGATION

PLATE M





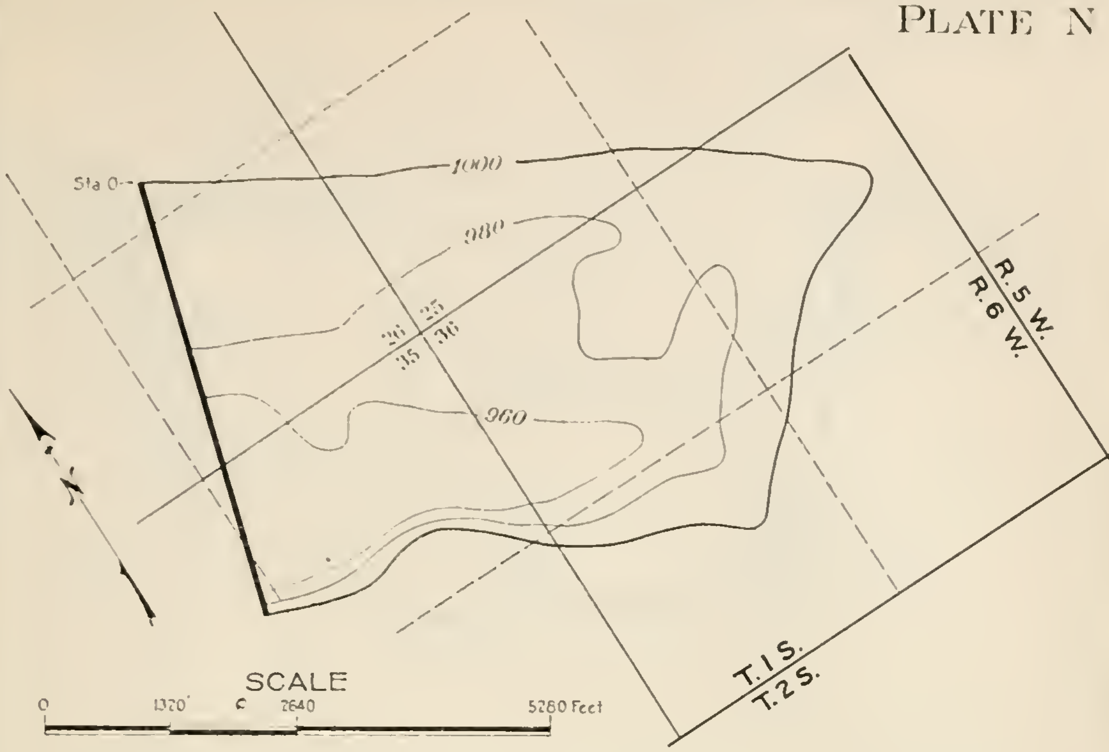


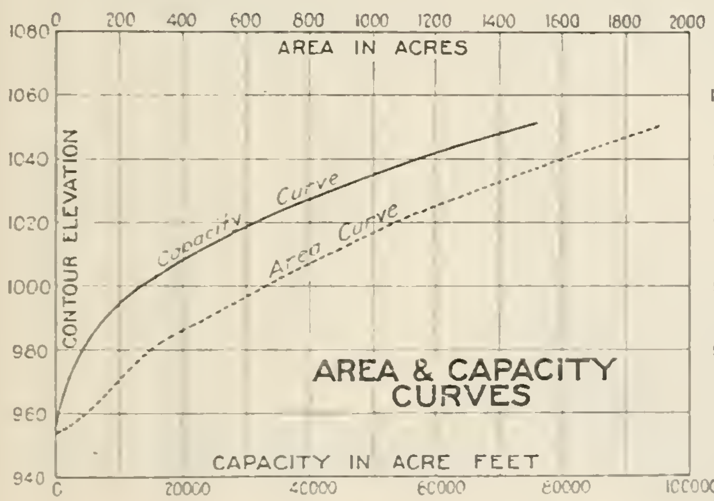
LITTLE MOUNTAIN RESERVOIR SITE

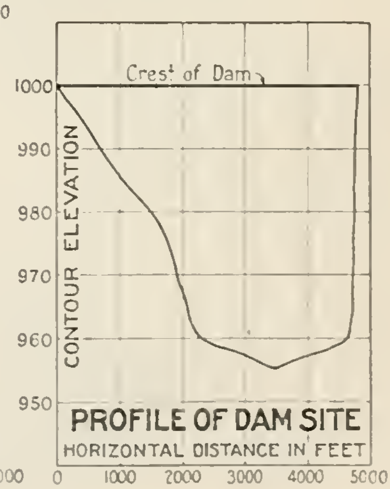
Type of Dam Earth Fill	(See Plate No. 2)
Height of Dam	50 Feet
Capacity	2600 Acre Feet
Elevation of Stream Bed	1310 Feet
Elevation of Crest	1360 Feet
Elevation of Spillway	1350 Feet
Width of Crest	20 Feet
Area of Reservoir	175 Acres
Estimated Cost	$964,000
Cost per Acre Foot of Storage	$370

SANTA ANA INVESTIGATION

PLATE N





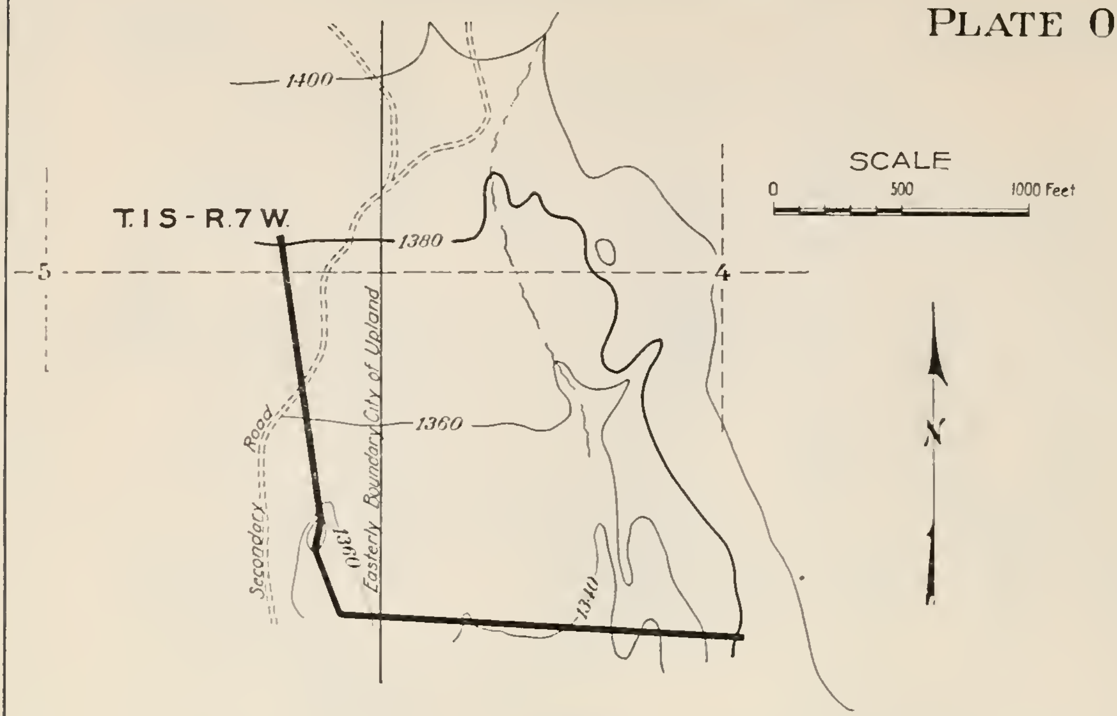


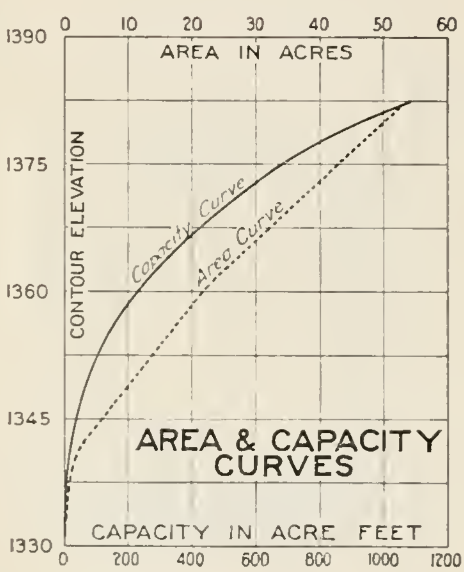
DECLEZ RESERVOIR SITE

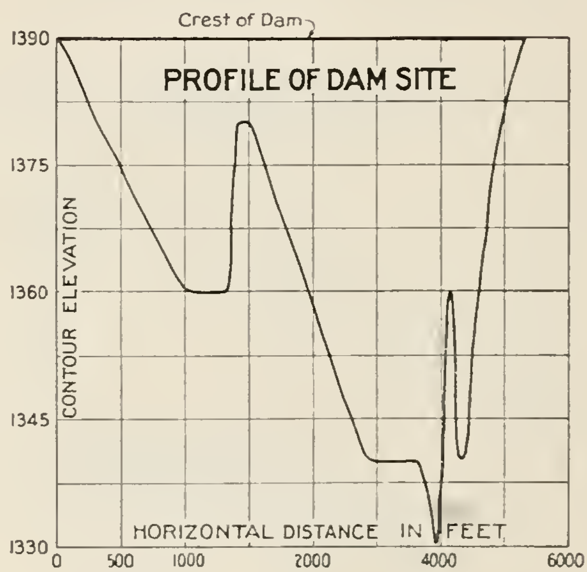
Type of Dam - Earth Fill.	(See Plate No. 2)
Height of Dam	45 Feet
Capacity	9,500 Acre Feet
Elevation of Stream Bed	955 Feet
Elevation of Crest	1000 Feet
Elevation of Spillway	990 Feet
Width of Crest	20 Feet
Area of Reservoir	480 Acres
Estimated Cost	$1,076,000
Cost per Acre Foot of Storage	$113.25

SANTA ANA INVESTIGATION

PLATE O





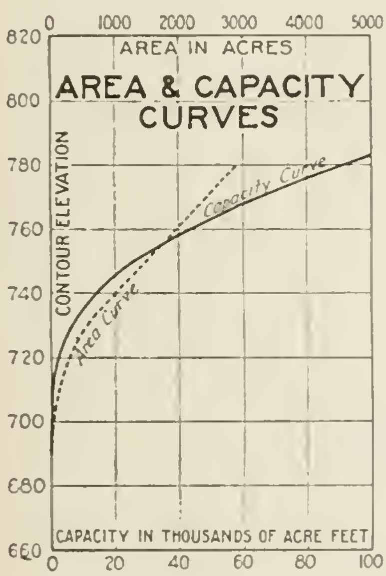


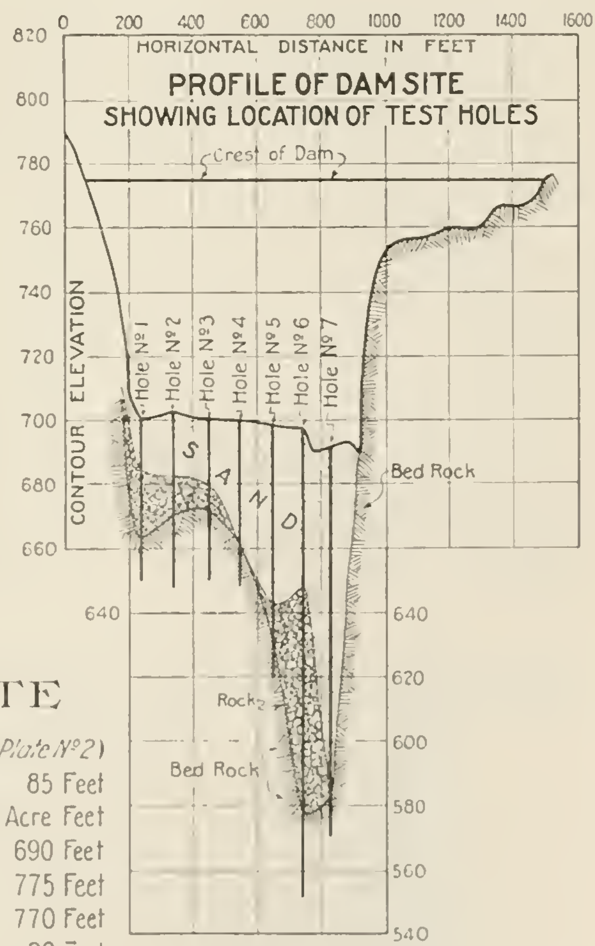
RED HILL RESERVOIR SITE

Type of Dam	Earth Fill	(*See Plate No 2*)
Height of Dam		60 Feet
Capacity		1000 Acre Feet
Elevation Stream Bed		1330 Feet
Elevation of Crest		1390 Feet
Elevation of Spillway		1380 Feet
Width of Crest		20 Feet
Area of Reservoir		50 Acres
Estimated Cost		\$617,000
Cost per Acre Foot of Storage		\$617

SANTA ANA INVESTIGATION

PLATE P



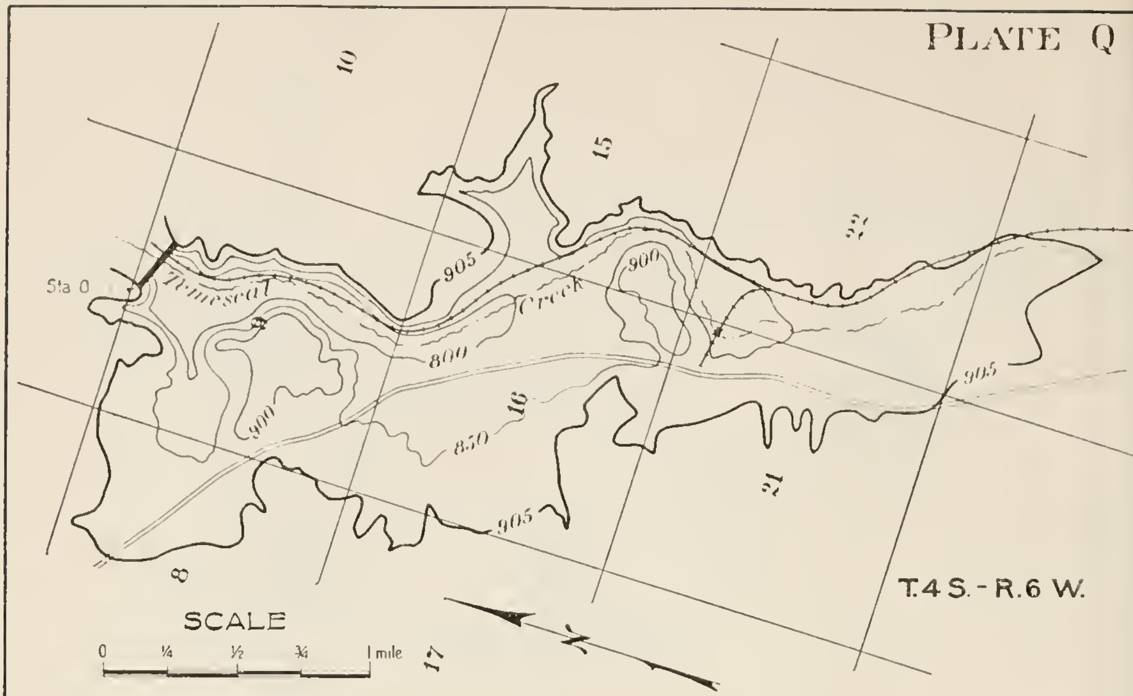


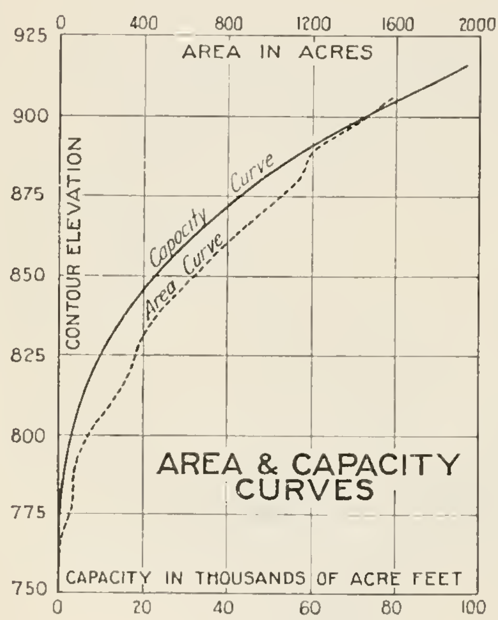
JURUPA RESERVOIR SITE

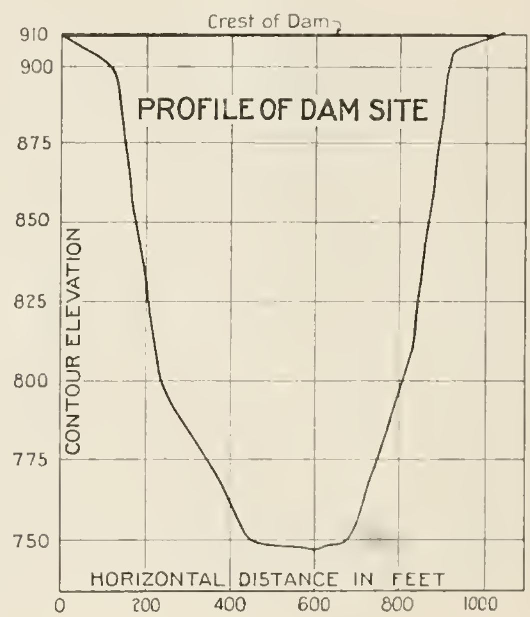
Type of Dam	Gravity Concrete	*(See Plate No 2)*
Height of Dam		85 Feet
Capacity		65,000 Acre Feet
Elevation of Stream Bed		690 Feet
Elevation of Crest		775 Feet
Elevation of Spillway		770 Feet
Width of Crest		20 Feet
Area of Reservoir		2,400 Acres
Estimated Cost		$7,300,000
Cost per Acre Foot of Storage		$112

SANTA ANA INVESTIGATION

PLATE Q





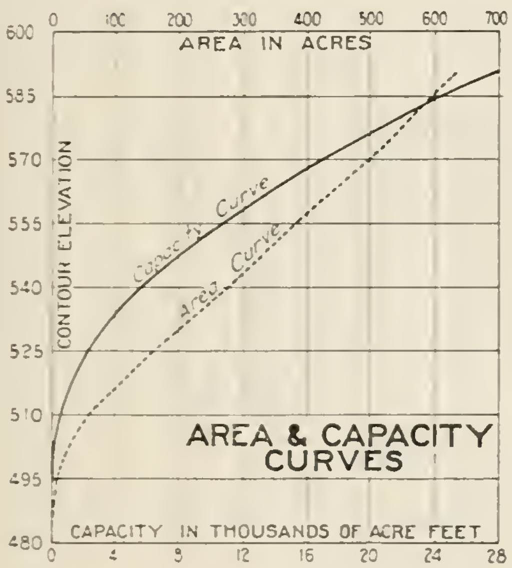


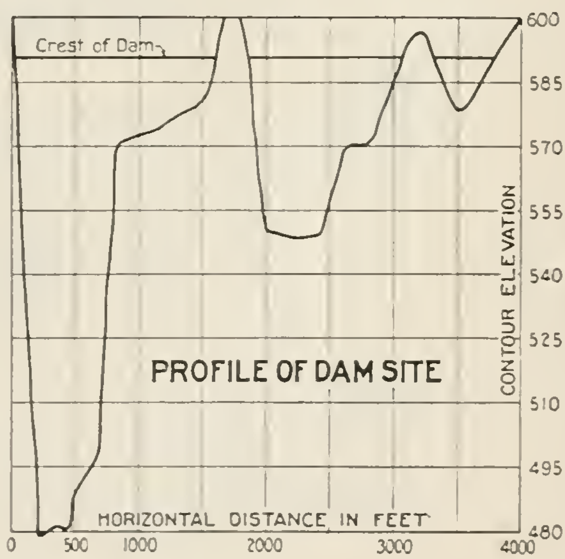
BLUE DIAMOND RESERVOIR SITE

Type of Dam	Gravity Concrete (*See Plate Nº 2*)
Height of Dam	160 Feet
Capacity	81,500 Acre Feet
Elevation of Stream Bed	750 Feet
Elevation of Crest	910 Feet
Elevation of Spillway	905 Feet
Width of Crest	20 Feet
Area of Reservoir	1615 Acres
Estimated Cost	$4,081,000
Cost per Acre Foot of Storage	$50

SANTA ANA INVESTIGATION

PLATE R





LOWER SANTIAGO RESERVOIR SITE

Type of Dam Earth Fill	*(See Plate Nº 2)*
Height of Dam	110 Feet
Capacity	23,600 Acre Feet
Elevation Stream Bed	480 Feet
Elevation of Crest	590 Feet
Elevation of Spillway	580 Feet
Width of Crest	20 Feet
Area of Reservoir	560 Acres
Estimated Cost	$1,188,000
Cost per Acre Foot of Storage	$50

SANTA ANA INVESTIGATION

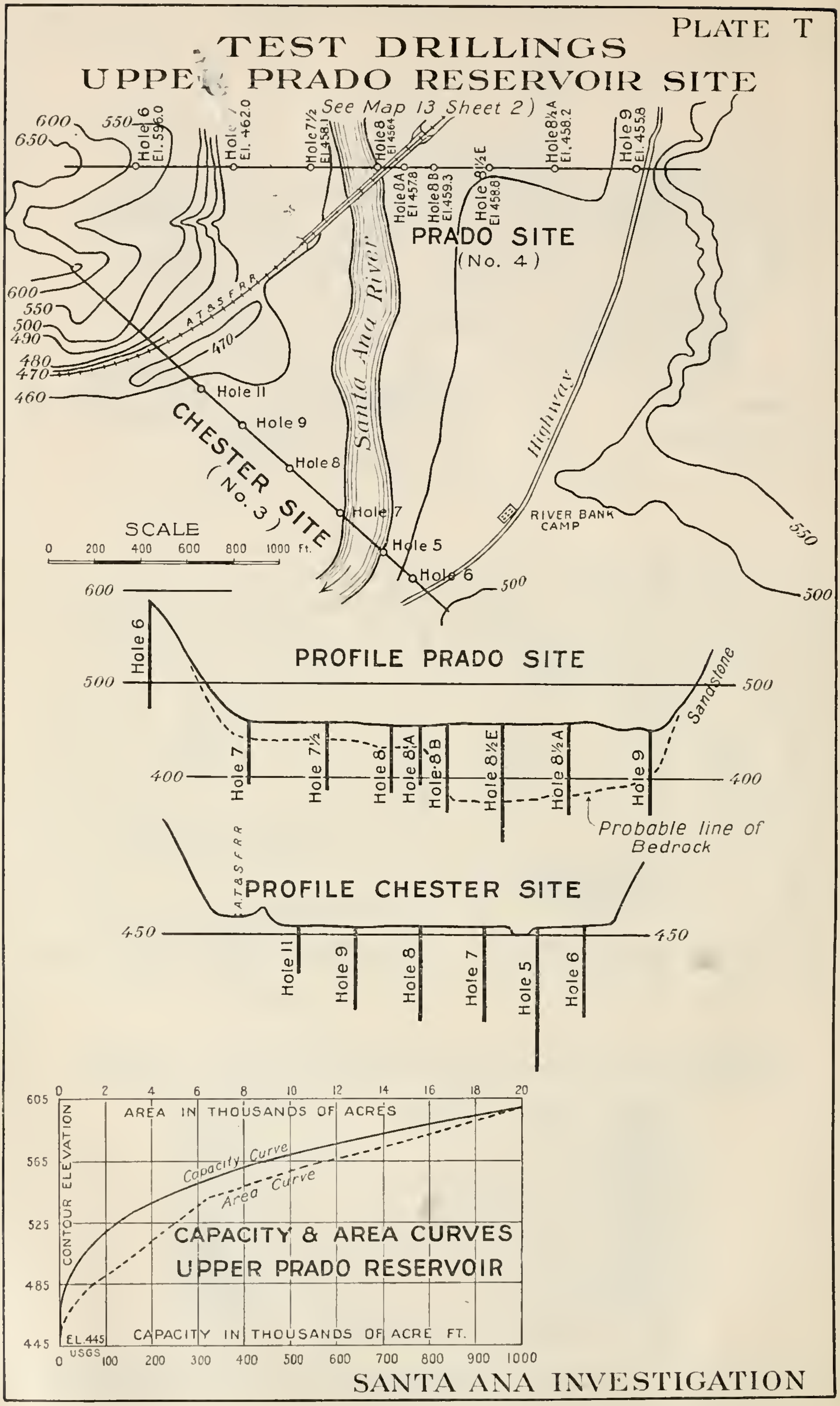
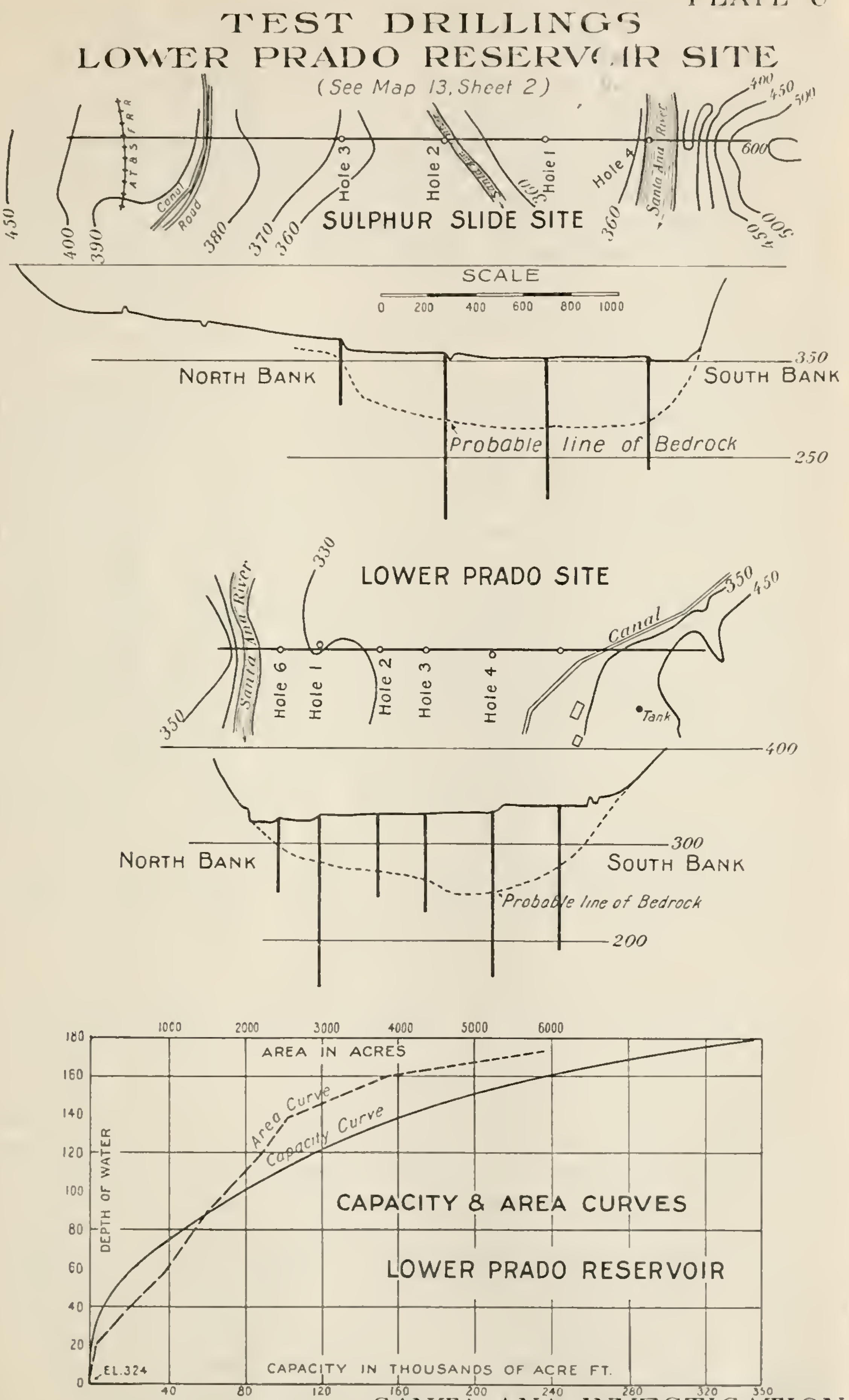


PLATE T
TEST DRILLINGS
UPPER PRADO RESERVOIR SITE
See Map 13 Sheet 2)
PRADO SITE
(No. 4)
CHESTER SITE
(No. 3)
Santa Ana River
Highway
A T & S F R R
RIVER BANK CAMP
SCALE
0 200 400 600 800 1000 Ft.
PROFILE PRADO SITE
Sandstone
Probable line of Bedrock
PROFILE CHESTER SITE
CAPACITY & AREA CURVES
UPPER PRADO RESERVOIR
AREA IN THOUSANDS OF ACRES
CAPACITY IN THOUSANDS OF ACRE FT.
CONTOUR ELEVATION
Capacity Curve
Area Curve
EL.445 USGS
SANTA ANA INVESTIGATION

PLATE U



SANTA ANA INVESTIGATION

27. **Santa Ana cone spreading grounds.** This cone lies immediately below the mouth of the canyon and contains an area of 5000 acres of rough gravel land suitable for spreading. The water plane at the upper end is from 50 to 150 feet below the surface and six miles away at the lower end it comes to the surface in the artesian area of San Bernardino. Water can be spread at the rate of 2 acre-feet per acre per day. If the entire area were utilized 10,000 acre-feet per day, equivalent to 5000 second-feet, could be absorbed. It is estimated that there were only 5 days in the last 32 years during which the river averaged such an amount continuously for 24 hours. Flood peaks of short duration have occurred with greater frequency. Assuming that the peaks were 2½ times the 24-hour average, it is estimated that the maximum flow would have been less than 5000 second-feet on all except 18 days of the 32 years.

The full utilization of these gravels would involve a low solid weir above in the mouth of the canyon to be massively constructed and to be a permanent diversion point. It would be capable of permitting the heaviest flood rushes to pass over it with their burden of drift and boulders. On the north side of this weir a tunnel would be constructed to divert 5000 second-feet, the inlet protected by gratings and supplemented by collection galleries. The tunnel would carry a high velocity, 20 feet per second or more, and convey the flood waters to the head of the gravel cone. At this point junction boxes and conduits would convey portions of the water to long spreading walls containing numerous openings. The velocity along these diagonal spreading walls would be 6 feet per second. Experience has shown that a properly designed spreading wall will take care of one second-foot per linear foot of wall. 5000 linear feet would be the minimum requirement to completely distribute the waters. These walls would probably be arranged in succession at intervals of one-half mile or more apart. At the lower end, to insure absolute safety of property below, there would be required a protection levee from the west bank of City Creek southerly to the vicinity of the E street San Bernardino bridge on the Santa Ana River. This protection levee would return all surplus water to the river.

The cost of the works described, exclusive of lands, would be $1,100,000. The utility of this work would be to regulate floods to the extent of 5000 second-feet at Mentone. Without any works above it, it would reduce the capital peak flood at Mentone from 52,000 to 47,000 second-feet. With Filirea Reservoir and Forks Reservoir built, the regulation would be 5000 second-feet over and above the regulation produced by these reservoirs, depending upon the capacity for which they were designed. If Filirea Reservoir is built for 4000 acre-feet capacity and Forks Reservoir for 20,000 acre-feet capacity and used as flood control reservoirs in connection with these spreading works the capital 24-hour flood of 30,000 second-feet would be reduced to 13,000 second-feet. The solid weir referred to above is not intended to be carried to bed rock, but is a type with only few examples in American practice. Examples are Laguna weir on the Colorado River, Granite Reef dam on the Gila River and the weir at spreading works on San Antonio Creek in Southern California. As such structures appear to be important at this stage of the development of the Santa Ana watershed the following extracts are made from the standard work on "Dams and Weirs" by W. G. Bligh.

SUBMERGED WEIRS FOUNDED ON SAND.

Description of type: There is a certain type of drowned or submerged diversion weir which is built across wide rivers or streams whose beds are composed of sand of such depth that a solid foundation on clay is an impossibility. Consequently, the weir has to be founded on nothing better than the surface of the river bed, with perhaps a few lines of hollow curtain walls as an adjunct. Of this class of weir but one is believed to have been constructed in the United States, viz, the Laguna weir over the Colorado River at the head of the Yuma irrigation canals.

This type originated in India and in that country are found numerous examples of weirs successfully constructed across very large rivers of immense flood discharge.

* * * * * * *

A weir built on sand is exposed not only to the destructive influences of a large river in high flood which completely submerges it, but its foundation being sand, is liable to be undermined and worked out by the very small currents forced through the underlying sand by the pressure of the water held up in its rear. In spite of these apparent difficulties, it is quite practicable to design a work of such outline as will successfully resist all these disintegrating influences, and remain as solid and permanent a structure as one founded on bed rock.

The experience in Southern California indicates that a steel deck as used on the San Antonio weir is necessary when dealing with large transported boulders.

28. **Mill Creek spreading grounds.** The identical soil weir is suggested for service on Mill Creek in the mouth of the canyon, as just described for the Santa Ana cone. A similar tunnel would convey the waters to the spreading grounds, which have a maximum area of 2,000 acres. A diagonal spreading wall 3,000 feet in length would be sufficient to absorb a maximum rate of 3,000 second-feet. This is without taking account of the very considerable spreading already provided where ditches are taken out at 8 separate headings.

The estimated capital flood, average of 24 hours, would not exceed 6,000 second-feet, although peaks of larger amount, possibly 10,000 second-feet, might be anticipated. The effect of this work would be to reduce the instantaneous peak from 10,000 to 7,000 second-feet. It would reduce the 24-hour discharge from 6,000 to 3,000 second-feet. The cost of this work would be $270,000, exclusive of land.

29. **Lytle Creek spreading grounds.** It is physically possible to organize spreading from Lytle Creek over a very extensive area on both sides of the river below the mouth of the canyon. On the east side an important work has already been initiated by the Lytle Creek Protective Association. This work now has an intake capacity of 320 second-feet. By the addition of another weir 2,000 second-feet additional could be spread upon 2,000 acres of land lying south and east of the present work. The cost on the east side would be $100,000. On the west side the following work is outlined. A solid weir may be constructed on the Turk Basin dam site, of the same type as previously described for the Santa Ana cone. A similar tunnel of 5,000 second-feet capacity would discharge into an open conduit of high velocity, which would feed successive lines of rock walls beginning at the mouth of the canyon and extending westerly in the direction of Etiwanda. There is available for this purpose 3,000 acres of land. The water plane is 400 feet below the surface and the storage capacity is greater

than the possible supply. At the lower end of such a 3,000-acre tract a protection levee would be brought together in the form of a V into a surplus water channel passing west of the town of Fontana and discharging into the Santa Ana River in the vicinity of Wineville, or impounded in the Declez Reservoir site previously described. The works on the west side would cost $500,000.

The utility of these works on the east and west side would be to reduce the capital peak flood of Lytle Creek from 28,000 second-feet to 21,000 second-feet. In connection with Turk Basin reservoir with 5,000 acre-feet capacity as a flood control reservoir, these works would reduce the capital 24-hour flood from 8,000 second-feet to 1,500 second-feet.

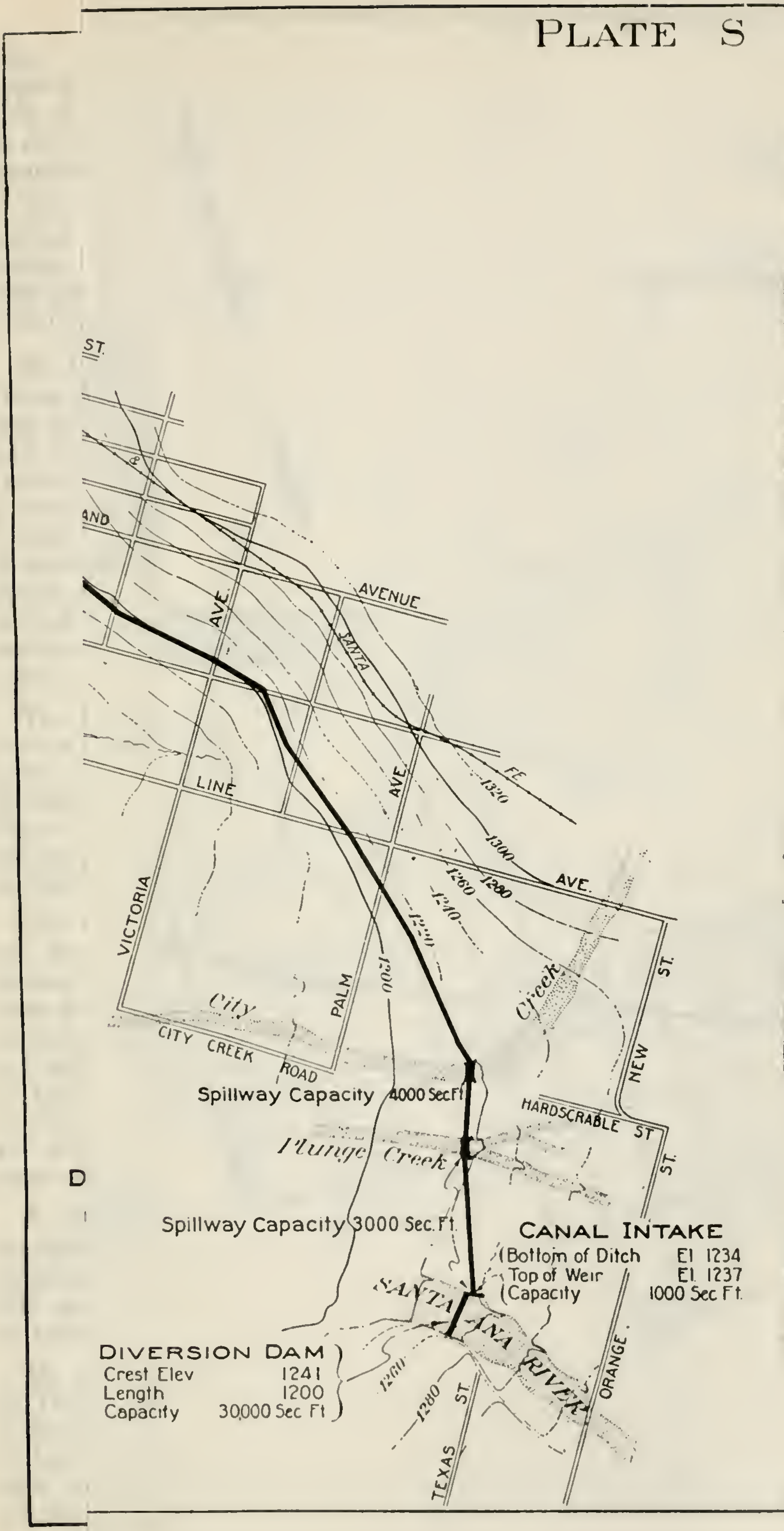
30. **Flood Control levees on San Antonio debris cone.** The existing spreading grounds are in process of complete development. The works of the Pomona Protective Association, together with the added works of Los Angeles County Flood Control, are anticipated to absorb the major portion of the waters of San Antonio Creek. The regimen of this creek, due to large snow storage at its head, is different from some of the others considered. The capacity of the intake is 320 second-feet. These works do not contemplate necessarily the diversion of the peaks of the floods. The existing main channel from the spreading works to the Santa Ana River should still provide for peak floods. The estimate for this channel improved by levees to care for peak floods is $150,000.

31. **Cucamonga spreading grounds.** The spreading grounds of the Cucamonga Water Company are already highly developed. The design of spreading works outlined in this report is suggested by these works, with the modification of using permanent construction in place of wire-bound rock walls. Additional development suggested would consist of a solid weir above the present structures and high velocity conduits diverting from each end of this weir to the gravel mesa on both sides of the river. At the lower end of each of these spreading grounds a protection levee should be built, gathering all waste again into the main channel or, preferably, first into Red Hill Reservoir site, previously described. This reservoir site would serve to utilize the waste waters and supply a small, regulated flow to the permanent storm drain, which would lead the waters to the Santa Ana River, by way of Chino Creek. The cost of such additional works would be $150,000.

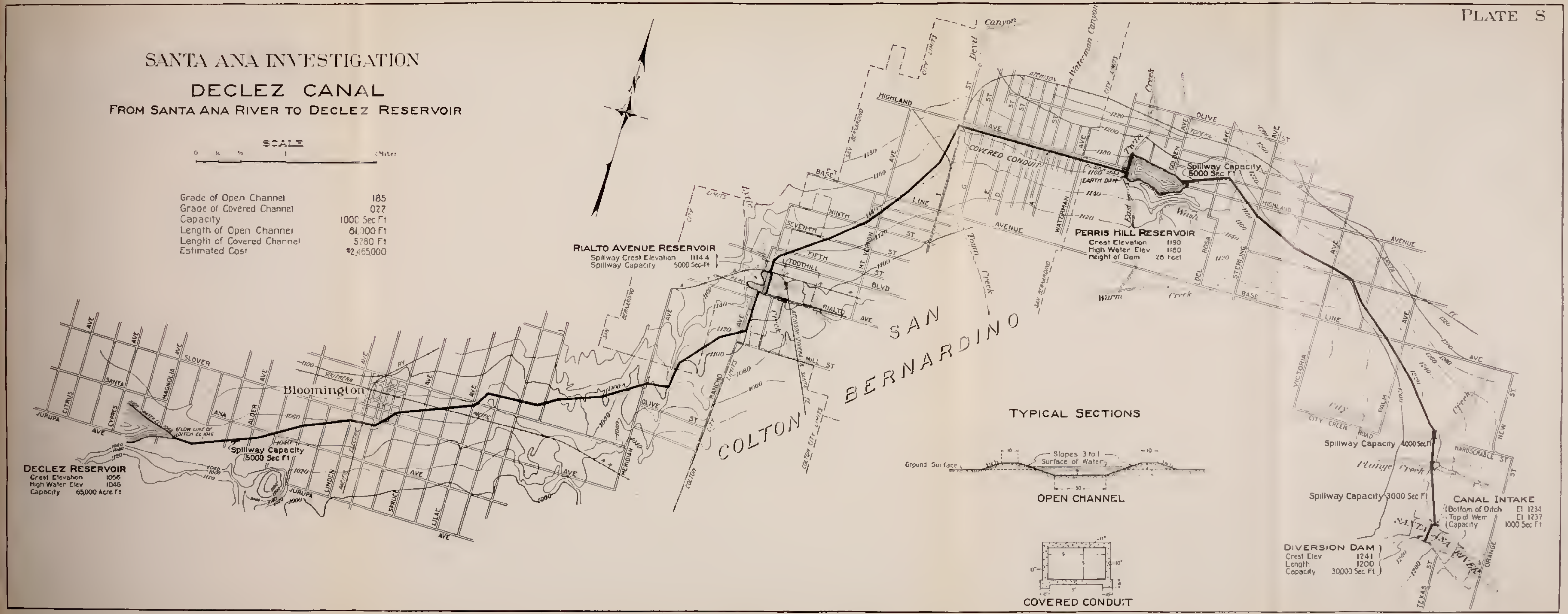
32. **Day and Etiwanda spreading grounds.** The work suggested on these streams would be to provide for the maximum floods by solid weir and diagonal spreading walls. The flood discharges are not as great and the existing works and natural conditions already serve in part to regulate floods. The estimated cost of these added works is $50,000.

33. **Anaheim Channel spreading grounds.** The old channel of the Santa Ana River from Yorba to Alamitos is more absorptive and more capable of intensive spreading than the existing channel. On the other hand, colonization and urban development and horticulture have pressed in upon this channel and it has ceased to exist except upon old maps. In spite of this condition efficiency of spreading would still indicate that provision for additional spreading is desirable in this

PLATE S



ST.
AND
AVENUE
AVE.
SANTA
FE
LINE
AVE.
1320
1300
1280
1260
1240
1220
1200
AVE.
VICTORIA
PALM
City
CITY CREEK ROAD
Creek
NEW ST.
Spillway Capacity 4000 Sec Ft.
HARDSCRABLE ST
Plunge Creek
ST.
Spillway Capacity 3000 Sec. Ft.
CANAL INTAKE
Bottom of Ditch El 1234
Top of Weir El. 1237
Capacity 1000 Sec Ft.
SANTA ANA RIVER
DIVERSION DAM
Crest Elev 1241
Length 1200
Capacity 30,000 Sec Ft
1260
1280
ST.
TEXAS
ORANGE
D


SANTA ANA INVESTIGATION
DECLEZ CANAL
FROM SANTA ANA RIVER TO DECLEZ RESERVOIR
SCALE
Grade of Open Channel 185
Grade of Covered Channel 022
Capacity 1000 Sec Ft
Length of Open Channel 81,000 Ft
Length of Covered Channel 5280 Ft
Estimated Cost $2,465,000
RIALTO AVENUE RESERVOIR
Spillway Crest Elevation 1114.4
Spillway Capacity 5000 Sec-Ft
PERRIS HILL RESERVOIR
Crest Elevation 1190
High Water Elev 1180
Height of Dam 28 Feet
Spillway Capacity 5000 Sec Ft
EARTH DAM
COVERED CONDUIT
DECLEZ RESERVOIR
Crest Elevation 1056
High Water Elev 1046
Capacity 65,000 Acre Ft
Spillway Capacity 5000 Sec Ft
Bloomington
COLTON
SAN BERNARDINO
TYPICAL SECTIONS
Slopes 3 to 1
Surface of Water
Ground Surface
OPEN CHANNEL
COVERED CONDUIT
Spillway Capacity 4000 Sec Ft
Spillway Capacity 3000 Sec Ft
CANAL INTAKE
Bottom of Ditch El 1234
Top of Weir El 1237
Capacity 1000 Sec Ft
DIVERSION DAM
Crest Elev 1241
Length 1200
Capacity 30,000 Sec Ft
SANTA ANA RIVER
Plunge Creek
City Creek
Twin Creek
Warm Creek
Lytle Creek
Waterman Canyon
Devil Canyon
HIGHLAND AVE
BASE LINE
FOOTHILL BLVD
RIALTO AVE
VICTORIA
STERLING
WATERMAN
MERIDIAN
LINDEN
LILAC
SPRUCE
CITRUS AVE
CYPRESS AVE
MAGNOLIA AVE
ALDER AVE
SLOVER
SANTA ANA
JURUPA AVE

63685

area. This utilization could be combined with a safety provision by making the spreading channel long and narrow and of a capacity not only to serve for spreading but also to conduct possible floods in safety to the ocean at the mouth of the San Gabriel River through this densely populated area.

The cost of a 500-foot channel with revetted levees from Yorba to Alamitos, including rights of way, is estimated to be $1,000,000. The utility for spreading for this channel would be a rate of 1,000 second-feet per day and its utility as a flood channel would be to take care of a 30,000 second-foot flood.

34. **Declez Canal.** This canal would serve as an intercepting and storm-gathering channel from the Santa Ana River at Palm Avenue east of San Bernardino and passing north and west of San Bernardino and Colton would terminate in Declez Reservoir, previously described. In the location shown on Plate 8, facing page 78, it will be seen that such a canal could divert the water in the main Santa Ana River, Plunge Creek, City Creek, Waterman Canyon and Lytle Creek. It also would be capable of gathering all surplus waters which are drained from the Santa Ana cone spreading grounds. As located this canal would pass behind Perris hill, which could be organized into a small equalizing reservoir to produce a more uniform flow in the canal beyond that point.

The capacity of the canal is taken as 1,000 second-feet. It would have a bottom width of 30 feet, and is estimated for gravel levees on both sides, protected by wire revetment and mattresses. Concrete spillways would be provided for excess capacity at Santa Ana River, City Creek and Lytle Creek crossings. The flood waters would be discharged into Declez Reservoir, previously described, with a capacity of 65,000 acre-feet.

The utility of this canal would be the removal of storm waters from the Santa Ana cone whenever an excess existed to a region where the ground water level is 100 feet or over in depth and where over-year storage is feasible and desirable and capable of extraction. This canal would serve as an intercepting storm drain for San Bernardino over a length of 8 miles. To a certain extent it would reduce the floods of Lytle Creek through the city of Colton. Such a canal might serve to impound 100,000 acre-feet in one storm year which now escapes to the ocean. The cost of the canal alone would be $2,465,000. As previously stated, the Declez Reservoir would cost $4,847,000.

35. **Little Mountain Canal.** This canal would carry the regulated discharge of Little Mountain Reservoir, previously described, westward to spreading grounds in Cajon and Lytle Creek. With a capacity of 200 second-feet, and a length of 4 miles, the cost is estimated at $80,000.

Its utility would consist in conservation in conveying flood waters of Devil, Waterman and East Twin creeks, temporarily detained in Little Mountain Reservoir to the depleted gravel area at the junction of Cajon and Lytle Creek. It would prevent flood water from passing into the streets of San Bernardino and conserve them in a favorable situation for extraction.

area. This utilization could be combined with a safety provision by making the spreading channel long and narrow and of a capacity not only to serve for spreading but also to conduct possible floods in safety to the ocean at the mouth of the San Gabriel River through this densely populated area.

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The capacity of the canal is taken as 1,000 second-feet. It would have a bottom width of 30 feet, and is estimated for gravel levees on both sides, protected by wire revetment and mattresses. Concrete spillways would be provided for excess capacity at Santa Ana River, City Creek and Lytle Creek crossings. The flood waters would be discharged into Declez Reservoir, previously described, with a capacity of 65,000 acre-feet.

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Its utility would consist in conservation in conveying flood waters of Devil, Waterman and East Twin creeks, temporarily detained in Little Mountain Reservoir to the depleted gravel area at the junction of Cajon and Lytle Creek. It would prevent flood water from passing into the streets of San Bernardino and conserve them in a favorable situation for extraction.

36. **Gage Canal, continuation of.** This would consist of extending the Gage Canal from its terminus near Arlington 7 miles to the Blue Diamond Reservoir. The capacity of the existing canal is 60 second-feet. The utility of such an extension would be the diversion of flood water of the upper Santa Ana River during the period of little or no irrigation use and storing it in Blue Diamond Reservoir. Its utility in this sense would be conservation, annual regulation and even over-year storage for use on lands near Corona or in Orange County. The cost of the extension of the Gage Canal is estimated at $500,000.

37. **Conservation Canal.** Taking the Jurupa Reservoir as an intake, a canal of 200 second-feet capacity may be located via Corona and end in the Lower Santiago Reservoir. The length by map contour is 35 miles, and is estimated to cost $3,000,000. The elevation at Jurupa Reservoir is 700. The high water level of Lower Santiago Reservoir site is 580 feet. The difference in elevation permits a grade of 1 foot per 1,000 feet in the canal.

By this disposition a power drop of 200 feet becomes available. The hydraulic construction would be entitled to a power credit on its first cost. In addition it should be credited with the salvage of evaporated waters in the natural channel.

The Lower Santiago Reservoir in connection with this plan would become a reservoir providing 24,000 acre-feet of annual storage for use of Santa Ana Valley Irrigation Canal, holding winter water for use in summer.

38. **Chino Canal.** In a similar manner the Jurupa Reservoir could act as an intake for a canal to Chino Reservoir, providing for 40,000 acre-feet of annual regulation for the Anaheim Canal. The cost is estimated at $775,000. It would assist in the salvage of waters of the natural channel to a certain extent.

39. **Salvage Canal.** On account of rising waters below Jurupa Reservoir amounting to one-third of the perennial flow through the lower Santa Ana canyon, an additional low level canal near the stream bed would be required for the complete unwatering of the natural bed. It is probable that the Conservation and Chino canals previously described would sufficiently reduce the water plane between Jurupa Reservoir and the mouth of Chino Creek to prevent evaporation. The Salvage Canal would be required below the mouth of Chino Creek to by-pass the waters through the canyon. It would be needed in any event to convey without loss waters from Chino Reservoir to the vicinity of the Anaheim and Santa Ana canal headings. The cost is estimated at $300,000. Salvage Canal somewhat extended would be an alternative to Conservation Canal.

40. **Irvine Canal.** This canal would be required to convey flood waters in the lower Santa Ana River to Irvine Reservoir. The length would be 5 miles and the capacity 5,000 second-feet. The intake would be in the vicinity of Fifth street bridge, Santa Ana. The estimated cost is $150,000.

The utility of this canal is to make effective the storage capacity of Irvine Reservoir, amounting to 16,800 acre-feet, previously described.

41. **San Bernardino moist area drainage.** This would be entirely a conservation measure. It would consist of reducing the water plane over an area of 6,000 acres permanently below the root zone. This has been accomplished elsewhere by drainage ditches or by shallow pumping. The drained water or the water drawn from shallow wells would be pumped to higher lands and utilized. No estimate has been made of cost.

The utility of this measure would be the salvage of evaporated water, which theoretically may amount to 20,000 acre-feet annually, and its use on adjacent lands. The reclamation of the moist area from sub-irrigated pasture and meadow to presumably more remunerative crops would be effected.

42. **Newport Pumping Plant.** The collection of waters of drainage ditches now discharging into the ocean, between Newport and Bolsa Chica, could be accomplished by a collecting canal, along the ocean front. The water could be pumped into the Irvine Reservoir continuously through the year, and taken again by pumping from Irvine Reservoir to the irrigated lands, as monthly demand would require. This reservoir would therefore provide annual regulation, and the entire drainage water could be conserved.

In connection with this drainage water conservation, the utilization of the effluent of the Metropolitan Sanitary Districts of Orange County might be joined. The principles governing sewage utilization are discussed on page 213. The drainage water may be found to afford the dilution required to permit sewage storage. The topic is presented only for further study. No authoritative opinion can be quoted on this subject.

43. **Sewage Canal from Los Angeles metropolitan area.** The physical situation is that the treatment plant of the Los Angeles sewage is distant 40 miles from the center of possible utilization in Orange County and the treatment plant of the Los Angeles County Sanitary District is 30 miles distant. No estimate of cost is made.

The utility of sewage utilization would be found in its dependability in dry seasons. It is an outside source and would be additional to the general stock of water. If a complete revision of domestic distribution were possible, using only gravity waters, or ground waters above possible pollution for domestic purpose and utilize sewage in designated areas, it might be possible to considerably extend the irrigated area. Further, the use of this sewage, appears limited by distance and cost to lands below an altitude above sea level of 150 feet, that is to lands in lower basin.

44. **Colorado River Aqueduct.** In Part II, page 214, is given a description of the Colorado River Aqueduct. On November 6th, 1928, certain cities in Santa Ana watershed voted upon their inclusion in the general water district, to be composed of some fifteen municipalities. Progress in respect to the Colorado River Aqueduct is dependent upon legislation by the United States Congress. In any event it is confined to municipal uses and its cost will correspond. Its significance in this report is because it is an addition from an outside source. The present domestic area in the Santa Ana watershed is 8 per cent of the total area and a large portion of the irrigated area is in small ownership

suburban in character. Water is distributed in many instances in the irrigated area in a manner similar to municipal distribution. The addition of Colorado River water may be reasonably anticipated to provide for the extension of municipal areas in the Santa Ana watershed for the future. It may even release water for irrigation on new lands by reason of the passing of lands now irrigated into municipal use.

45. **City Creek Levee.** A protection work is outlined from the west bank of City Creek at Base Line avenue, southwesterly to the north bank of the Santa Ana River and thence along the Santa Ana River to E street bridge of San Bernardino. This would consist of a gravel levee 10 feet high, 10-foot crown, 3 to 1 slopes, the upstream side protected with a wire mattress, including 5-foot apron. The length would be 40,000 linear feet and the cost estimated at $704,000. The utility of this protection work would be to protect the city of San Bernardino and vicinity from floods of City Creek, Plunge Creek and Santa Ana River. It would have a utility in gathering the surplus waters which are now, or may be spread on the Santa Ana cone and safely returning them to the main Santa Ana River channel. If spreading is practised on a great scale sufficient to regulate floods on the Santa Ana cone such a protective work would be necessary, not only to insure the return of surplus waters to the river, but also to guard against the failure of any particular spreading work.

46. **Levee at Colton on the Santa Ana River.** A double levee may be provided between E street bridge and the Riverside road bridge immediately south of Colton. This protective work is estimated to cost $100,000.

47. **Lytle Creek protection works.** A single levee is required between Highland avenue and Foothill boulevard on Lytle Creek to conduct this stream in one channel. This levee would be 6,000 linear feet in length. It would be 10 feet high, 10-foot crown, slopes 3 to 1, and upstream side protected with wire mesh mattress. It is estimated to cost $100,000.

From Foothill boulevard to the mouth of Lytle Creek a relocated channel midway between the present east and west channels is required involving the removal of houses which are now in the storm track. This work is required for protection of life. It would consist of a double levee of the same type, 10,000 linear feet in length, and is estimated to cost $430,000.

48. **San Timoteo Creek levee.** There is required on San Timoteo Creek a double levee 6 feet high, of similar construction, for a length of 27,000 linear feet of relocated channel. The estimated cost is $600,000.

49. **Lower Santa Ana River Levee.** There is required a single levee from Yorba to Fifth street bridge in Santa Ana of a total length of 90,000 feet. This levee would be 10 feet high, 10-foot crown, and protected by piling and wire revetment and is estimated to cost $1,500,000.

There is required a widening of the present levee channel from Fifth street bridge to the ocean to a width of 500 feet. This would involve the moving and rebuilding of one levee and the providing of piling and wire mesh protection for both levees of a length of 200,000 feet. The cost is estimated at $3,500,000.

50. **Protection works at San Jacinto and Perris.** Reservoir sites exist in the headwaters of the San Jacinto River, on Strawberry Creek, North Fork of the San Jacinto River, Bautista Creek and Potrero Creek, which if built would have a limited effect on floods. These have not been studied for flood control possibilities. Channel control by levees is desirable at the city of San Jacinto. The structure would have a length of 10,000 feet. It would be 10 feet high, 10 foot crown and protected by wire mesh mattress, and is estimated to cost $150,000.

South of Perris pondage of the San Jacinto River occurs over a large area during major floods. This is in part due to lack of openings in the railway and highway embankment. Combined with bridges of greater capacity and perhaps an excavated and rectified channel, a levee system would limit the extent of the overflow. No estimate is made of the cost of these works.

CHAPTER 6

ILLUSTRATIVE COMBINATIONS OF UNITS INVESTIGATED.

Combination A. Channel easements and bank protection. In any plan, official beds for flood channels should be provided. In any plan, bank protection along the lines of the official channels should be provided wherever the streams are not flowing between bluffs. This combination is the simplest and represents the situation as of today. There are few unrelated scattered protection works. There are a few bridges with wing walls of greater or less extent. There are private bulkheads on individual properties.

The works called for in this combination would be as follows: Easements for official channels; City Creek levee, levee along Santa Ana River at Colton, Lytle Creek levee, San Timoteo Creek levee, levees from Yorba to Santa Ana and widening of present channel from Santa Ana to the ocean.

The cost of the official channels is estimated to be $1,500,000 and of the protective works $7,400,000.

Combination B. Combination B is for flood control, consisting of Forks, Turk Basin, Prado and Lower Santiago flood control reservoirs and has been worked out for two sizes of Prado Reservoir as shown in the following paragraphs. This assumes that combination A would be adopted in a whole or in part. This group of works would consist of Forks Reservoir, built to a height of 310 feet, a capacity of 20,000 acre-feet and a cost of $8,000,000; Turk Basin, with a height of 155 feet, a capacity of 5000 acre-feet and a cost of $4,000,000; Prado Reservoir with a height of dam 80 feet, a capacity of 95,000 acre-feet and a cost of $6,000,000; and Lower Santiago Reservoir with a height of dam of 110 feet, a capacity of 23,600 acre-feet, and a cost of $1,200,000; a total cost of $19,200,000.

The results to be obtained by this combination are that the capital peak flood at Mentone would be reduced from 52,000 to 20,000 second-feet, the capital peak flood at Colton would be reduced from 80,000 to 50,000 second-feet, the capital peak flood at Yorba would be reduced from 86,000 to 22,000 second-feet and the capital peak flood at Santa Ana would be reduced from 100,000 to 23,300 second-feet.

The 24-hour average capital flood would become at Mentone 20,000 second-feet, at Colton 50,000 second-feet, at Yorba 22,000 second-feet and at Santa Ana 23,300 second-feet.

This is shown in detail in the following tabulation illustrative of the action of flood control reservoirs. The Forks Reservoir provides an opening at all times of 20,000 second-feet, Turk Basin an opening of 6000 second-feet, Prado an opening of 22,000 second-feet, and Lower Santiago an opening of 2300 second-feet.

Capital flood as regulated by Combination B

Upper Santa Ana River

Day of flood	Santa Ana at Mentone, daily discharge		Storage Forks reservoir, acre-feet	Below Forks reservoir, acre-feet	Absorption in channel, acre-feet	Net reaching Prado reservoir, acre-feet
	Second-feet	Acre-feet				
1	1,900	3,800	0	3,300	2,000	1,800
2	30,000	60,000	20,000	40,000	8,000	32,000
3	4,000	8,000	0	24,000	4,000	20,000
4	2,000	4,000	0	4,000	1,000	3,000
5	2,000	4,000	0	4,000	1,000	3,000
6	2,000	4,000	0	4,000	1,000	3,000

Lytle Creek

Day of flood	At Turk Basin, daily discharge		Storage in Turk Basin, acre-feet	Below Turk Basin, acre-feet	Absorption in channel acre-feet	Net reaching Prado reservoir, acre-feet
	Second-feet	Acre-feet				
1	6,000	12,000	0	12,000	3,000	9,000
2	9,500	19,000	5,000	14,000	3,000	11,000
3	2,000	4,000	0	9,000	1,000	8,000
4	2,000	4,000	0	4,000	1,000	3,000
5	2,000	4,000	0	4,000	1,000	3,000
6	1,200	2,400	0	2,400	600	1,800

Floods partially regulated reaching Prado Reservoir

All in acre-feet

Day of flood	Upper Santa Ana as regulated	Mill	Plunge	City	Cable, Devils, Waterman and Strawberry	Cajon and Lone Pine	Lytle as regulated	San Timoteo
1	1,800	1,600	2,800	4,600	1,000	2,000	9,000	8,800
2	32,000	11,600	7,000	8,800	4,000	4,600	11,000	14,200
3	20,000	4,000	2,400	2,600	1,600	2,000	8,000	1,000
4	3,000	1,200	1,000	1,400	600	200	3,000	0
5	3,000	800	600	800	400	0	3,000	0
6	3,000	500	400	600	200	0	1,800	0

Day of flood	Warm Creek and valley floor	Local drainage between Colton and Pedley	Temescal	Chino	Total Santa Ana River reaching Prado	Storage Prado reservoir	Regulated outflow
1	3,000	2,000	5,000	500	42,100	0	42,100
2	6,000	4,000	20,000	3,000	126,200	82,200	44,000
3	3,000	2,000	8,000	1,600	56,200	94,100	44,000
4	800	1,000	2,000	600	14,800	65,200	44,000
5	600	200	1,000	200	10,600	31,800	44,000
6	500	200	800	200	8,200	0	40,000

Santiago Creek, regulated by Lower Santiago Reservoir

Day of flood	Santiago Creek, daily discharge		Storage	Regulated outflow
	Second-feet	Acre-feet	Acre-feet	Acre-feet
1	1,200	2,400	0	2,400
2	14,000	28,000	23,400	4,600
3	2,400	4,800	23,600	4,600
4	600	1,200	20,200	4,600
5	550	1,100	16,700	4,600
6	500	1,000	13,100	4,600

Santa Ana River at Santa Ana as regulated

Prado Reservoir—95,000 acre-feet

Day of flood	Santa Ana River below Prado reservoir	Santiago Creek below Lower Santiago reservoir	Absorption in Channel	Regulated flow at Santa Ana
	Second-feet	Second-feet	Second-feet	Second-feet
1	21,000	1,200	1,000	21,200
2	22,000	2,300	1,000	23,300
3	22,000	2,300	1,000	23,300
4	22,000	2,300	1,000	23,300
5	22,000	2,300	1,000	23,300
6	20,000	2,300	1,000	21,300

On page 60, in the description of Upper and Lower Prado Reservoir sites, there has been already indicated the tentative program of Orange County Flood Control. This program would carry combination B to almost the maximum development. The present channel of the river from the city of Santa Ana to the ocean is enclosed in levees, the width being 400 feet near Santa Ana, 350 feet midway and 300 feet near the mouth. The United States Geological Survey shows an average 24-hour discharge of 13,000 second-feet and a peak discharge of 25,000 second-feet. With this discharge breaks in the levee on the northwest side occurred. With a rectification of the width, it would appear that 23,000 second-foot floods as heretofore shown in combination B could be carried.

The tentative plan of Orange County Flood Control would provide 180,000 acre-feet of storage, and contemplates a discharge of 1,000 second-feet for minor and ordinary floods changing to 5,000 second-feet when the reservoir is half full. This storage together with the other reservoirs would require for the capital flood openings with capacity of 7,000 second-feet and a channel capacity below city of Santa Ana of 8,300 second-feet. The total cost for this modification of combination "B" is estimated at $21,000,000 to $25,000,000 depending on which reservoir is constructed in Lower Santa Ana Canyon. The performance of this modification is shown in the following tabulation:

Prado Reservoir with 180,000 acre-feet capacity in combination with Forks, Turk Basin and Lower Santiago reservoirs

Santa Ana River at Prado

Day of flood	Total Santa Ana River reaching Prado acre-feet	Storage in Prado reservoir acre-feet	Regulated outflow	
			Acre-feet	Second-feet
1	42,100	28,100	14,000	7,000
2	126,200	140,300	14,000	7,000
3	56,200	182,500	14,000	7,000
4	14,800	183,300	14,000	7,000
5	10,600	179,900	14,000	7,000
6	8,200	174,100	14,000	7,000

Santa Ana River at Santa Ana as regulated

Day of flood	Santa Ana River below Prado reservoir second-feet	Santiago Creek below Lower Santiago reservoir second-feet	Absorption in Channel second-feet	Regulated flow at Santa Ana second-feet
1	7,000	1,200	1,000	7,200
2	7,000	2,300	1,000	8,300
3	7,000	2,300	1,000	8,300
4	7,000	2,300	1,000	8,300
5	7,000	2,300	1,000	8,300
6	7,000	2,300	1,000	8,300

If no flood control reservoirs were installed above, but Lower Santiago Reservoir was installed, the required opening for capital flood conditions in Prado Reservoir and the channel capacity to the ocean would be the same. The estimated cost is $13,000,000.

If no reservoirs were built except Prado, the outlets in Prado would be for 7,000 second-feet, and the required channel capacity to the ocean would be 20,000 second-feet, as shown in the following tabulation. The estimated cost is $11,800,000.

Stream as concentrated at city of Santa Ana solely regulated by Prado Reservoir with 180,000 acre-feet capacity

Day of flood	Santa Ana below Prado reservoir second-feet	Santiago Creek second-feet	Absorption in Channel second-feet	Regulated flow at Santa Ana second-feet
1	7,000	1,200	1,000	7,200
2	7,000	14,000	1,000	20,000
3	7,000	2,400	1,000	8,400
4	7,000	600	1,000	6,600
5	7,000	600	1,000	6,600
6	7,000	500	1,000	6,500

Combination C. Combination C is alternative to Combination B. In this combination Forks, Turk Basin and Lower Santiago reservoirs are used as in combination B. Blue Diamond and Jurupa reservoirs have been substituted for the Prado Reservoir. Jurupa Reservoir with a capacity of 65,000 acre-feet requires a dam 85 feet high and will cost $7,300,000. Blue Diamond Reservoir with a capacity of 31,000 acre-feet requires a dam 110 feet high and will cost $1,600,000.

The result of this combination C would be to regulate peak floods sufficiently to make a uniform 24-hour flow in the main river as before.

The 24-hour flood would be reduced at Mentone, as before, to 20,000 second-feet; at Colton to 50,000 second-feet; at Pedley Bridge to 21,000 second-feet; at Yorba to 23,000 second-feet and at Santa Ana to 24,300 second-feet, as shown in the following tabulation.

Floods of Santa Ana River partially regulated reaching Jurupa Reservoir (as previously given under combination B omitting Temescal and Chino Creeks).

Santa Ana River as Regulated at Jurupa

Day of flood	*Total Santa Ana River reaching Jurupa Reservoir acre-feet*	*Storage Jurupa Reservoir acre-feet*	*Regulated outflow acre-feet*
1.	37,600	0	37,600
2.	101,200	59,200	42,000
3.	46,600	63,800	42,000
4.	12,200	34,000	42,000
5.	9,400	1,400	42,000
6.	7,200	0	8,600

Temescal Creek as Regulated by Blue Diamond Reservoir

Day of flood	*Temescal above Blue Diamond Reservoir acre-feet*	*Storage acre-feet*	*Regulated outflow acre-feet*
1.	5,000	4,000	1,000
2.	20,000	23,000	1,000
3.	8,000	30,000	1,000
4.	2,000	31,000	1,000
5.	1,000	31,000	1,000
6.	800	30,800	1,000

Santa Ana River as Regulated at Santa Ana

Day of flood	*Santa Ana River below Jurupa Reservoir sec.-ft.*	*Temescal Creek below Blue Diamond Reservoir sec.-ft.*	*Chino Creek unregulated sec.-ft.*	*Santiago Creek below Blue Diamond Reservoir sec.-ft.*	*Absorption in channel sec.-ft.*	*Regulated flow at Santa Ana sec.-ft.*
1.	18,800	500	250	1,200	1,000	19,750
2.	21,000	500	1,500	2,300	1,000	24,300
3.	21,000	500	800	2,300	1,000	23,600
4.	21,000	500	300	2,300	1,000	23,100
5.	21,000	500	100	2,300	1,000	22,900
6.	4,300	500	100	2,300	1,000	6,200

Combination D. This combination in addition to Forks, Turk Basin, Jurupa, Blue Diamond, and Santiago reservoirs, includes spreading works on the Santa Ana River, Mill Creek, Lytle Creek and Anaheim channel.

The spreading works on the Santa Ana cone would provide for reduction of 24-hour maximum floods by 5000 second-feet, the works on Mill Creek 3000 second-feet and on Lytle Creek 5000 second-feet, or a total of 13,000 second-feet. The effect would be to decrease the 24-hour flood at Colton by this amount.

It would result in a reduction of the discharge obtained by storage in Jurupa or Prado at least 6000 second-feet. Provision of spreading works in the vicinity of Anaheim would absorb 1000 second-feet additional to present conditions. The regulated outflow maximum already given of approximately 23,000 second-feet at Santa Ana would be reduced to at least 16,000 second-feet.

The estimated cost of these spreading works is $2,000,000.

Combination E. Assuming that flood control were reasonably accomplished by some of the preceding combinations, combination E takes up the additional works required to secure complete over-year storage of the present waste into the ocean. This requires the storage of approximately 286,000 acre-feet in one maximum year, to regulate the waste, which will then yield a uniform supply of 33,000 acre-feet.

In the maximum year flood control works of combination B, C or D would incidentally conserve and store in gravels 50,000 to 100,000 acre-feet over and above the absorption by natural channels and existing spreading works. Therefore additional conservation reservoirs of from 186,000 to 236,000 acre-feet would be required.

Conservation reservoirs in the following list would accomplish the remaining storage required, either by actual over-year storage within the reservoir or by retention sufficient for systematic and complete spreading in the vicinity.

Reservoir	*Acre-feet*
Singleton	7,500
Yucaipa	5,500
Little Mountain	50,000
Deelez	65,000
Blue Diamond	50,000
Upper Santiago	32,000
Irvine	17,000
	247,000

The cost of this group of conservation reservoirs is estimated at $27,000,000.

Combination F. Even if flood control works and conservation reservoirs in the preceding combinations were not built, it is possible to provide for annual regulation to the following extent. This is purely conservation.

Reservoir	*Acre-feet*
Filirea	4,000
Myer, with tunnel from Turk Basin Reservoir	5,000
Chino, with canal from Jurupa Reservoir	39,000
Lower Santiago, with canal from Jurupa Reservoir	23,600
	71,600

The cost of this group would be $11,000,000.

Combination G. Complete Salvage. In addition to combination F, works of salvage to completely dry the natural channel of the Santa Ana River from mouth of Chino Creek to Yorba, except in times of flood, will result in salvage. The works would consist of a canal parallel to the Santa Ana River from the mouth of Chino Creek to the head of the Anaheim and Santa Ana canals supplemented with galleries and drains to gather the rising waters. There would also be required a branch to connect Chino Reservoir with this canal.

Combination H. Power Recovery. In connection with certain features of preceding combinations, power would be recoverable at Lower Santiago Reservoir at the lower extremity of the Conservation Canal, where a fall of 200 feet is available.

Power is also obtainable in connection with Filirea Reservoir where the fall from the reservoir to the junction of Bear Creek is 900 feet.

Power is also obtainable from the regulated flow of Lytle Creek, provided either Turk Basin or Myer Reservoir is used not for flood control but for conservation. The fall from the mouth of the canyon to the existing Fontana power house is 800 feet.

CHAPTER 7

OTHER RELATED SUGGESTIONS

Stream measurements. This investigation continues the intensive measurement of streams which are not measured by the U. S. Geological Survey, until December 1, 1928. It is suggested that action be taken by the counties or other public bodies to assure the continuance of these stream measurements, office computations and annual publication. This may be arranged either by placing the necessary funds at the disposal of the U. S. Geological Survey or by the appointment of an hydrographer reporting to such public bodies. This hydrographic work should include cooperation with existing water organizations for uniform reports and measurement of their respective diversions. In many instances the total run-off of a stream is the sum of the diversion and the flow in the channel.

Statistical information. It is suggested that the counties or other public organization provide the funds for the continuance of collection of statistical information such as irrigated area, rainfall, and use of water.

Topographic map. It is suggested that the counties initiate a cooperation with the topographic branch of the United States Geological Survey for a map of the inhabited portion of the counties, in scale and information similar to the recently completed map of Los Angeles County.

Preservation of bench marks. It is suggested that provision be made in a similar manner in cooperation with county engineers, engineers of water organizations and the State Division of Highways, to provide permanent bench marks upon all culverts, bridges, intake works, dams, and other prominent natural objects showing the elevations. Such bench marks should be reduced to mean sea level datum U. S. G. S., and published.

CHAPTER 8

FLOOD DAMAGE

Flood damage in 1916 and 1927 together with data on annual income has been collected by Francis Cuttle, president, Water Conservation Association, the authority being given as follows:

> The data with reference to the probable annual income from this territory was received from the Horticultural Commissioners and Farm Advisors in the three counties, the data with reference to storm damage, was taken from a report of the U. S. G. S. (Water Supply Paper 426, Southern California Floods of January, 1916) and damage in 1927 was estimated by the county surveyors of the three counties.

These data have been assembled in the following tabulation, preceded by assessed valuation as given in Table 1, page 97 of this report.

Property Within Watershed and Dependent on Santa Ana River

	San Bernardino County	*Riverside County*	*Orange County*	*Los Angeles County*
Assessed valuation, 1927	$64,148,000	$29,693,000	$155,578,000	$13,397,000
Probable annual income, 1927	30,192,000	15,213,000	37,982,000	--------
Storm damage, 1916	400,000	605,000	521,000	--------
Storm damage, 1927	175,000	300,000	350,000	--------

The damage to public works on the Santa Ana watershed by the storm of 1916 has been described in detail in Water Supply Paper, 426, U. S. Geological Survey, as follows:

> San Bernardino County.—Nearly 40 bridges, including 3 across Santa Ana River, were washed out or damaged. The cost of replacement and repairs was about $67,524. The roads in every section of the county were seriously damaged. On Turner avenue, Cucamonga, the entire street was washed out from 4 to 12 feet in depth for a distance of 4½ miles. Cajon and Mill Creek roads were badly washed and required extensive repairs. The damage to roads and culverts was about $80,656. The injury to state highways, including repairs made during the storms, was about $6,950.
>
> Riverside County.—The damage to 15 bridges, including 4 across Santa Ana River, was about $78,100. Several roads were badly washed out and the loss was approximately $32,000. The injury to state highway, including repairs made during the storms, was about $18,500.
>
> Orange County.—Almost the entire mileage of mountain roads will have to be rebuilt, as the grades were badly washed or buried by slides. The other graded and oiled roads were slightly damaged by deposits of debris and occasional washouts. The injury caused by undermining and shoulder cutting of paved highway was nominal. The loss of bridges was not considered, as they were old wooden structures which should have been replaced. The total damage was about $45,000. In addition, the state highway loss was approximately $36,500 including repairs made during the storms.

Damage Subsequent to 1916.

In San Bernardino County, in 1927, many roads were put out of service, and public bridges on San Timoteo Creek were destroyed, with a loss of $20,000.

In Riverside County, Mr. A. C. Fulmor, county surveyor, reported as follows to the board of supervisors on public losses by flood of February 15-17, 1927:

Bridge	*Estimated replacement cost*
Hamner, Santa Ana River	$10,000
Auburndale, Santa Ana River	20,700
Rincon, Santa Ana River	4,700
Serrano, Chino Creek	200
Corona, Temescal Creek	10,000
	$45,600

In Orange County, Mr. W. K. Hilliard, county surveyor, reports the following on public losses:

"In 1922 a short portion of the Santa Ana Canyon road at Gypsum Creek was washed out. In 1926 two short portions of the Santa Ana Canyon road near the county line were washed out."

PART II

COLLECTED INFORMATION

ESTIMATES AND ANALYSES

CHAPTER 1

DIGEST OF COLLECTED INFORMATION AND TECHNICAL RESULTS

The Five Basins Described. For purposes of description and analysis, the Santa Ana River watershed has been divided into five basins: Upper, Jurupa, Cucamonga, Temescal and Lower. The boundaries of these basins are in part the topographic watershed limits, in part more or less well recognized subterranean barriers or divides of underground water and on the west the boundary of Los Angeles County.

The San Jacinto Basin is not included. It is considered to terminate normally in Lake Elsinore, and only occasionally overflows into Temescal Creek. A complete report on the San Jacinto Basin was made by the Department of Public Works, Division of Water Rights, in 1922, prepared by S. T. Harding, entitled "Report on San Jacinto River Hydrographic Investigation."

Upper Basin is the watershed lying above the Bunker Hill barrier, a line northwesterly and southeasterly between the cities of San Bernardino and Colton. It includes all streams on the mountain front from Lytle Creek to San Timoteo Creek.

Jurupa Basin is the watershed of the Santa Ana River below the Bunker Hill barrier and above Pedley Bridge. It includes on the south the streams from Reche Canyon to Mocking Bird, and the Jurupa Hills and Slover Mountain on the north.

Cucamonga Basin is bounded by the topographic divide of Pomona Hills and the mountain front from San Antonio Creek inclusive, to Lytle Creek exclusive, the underground hydrographic divide of the Jurupa Basin, and by the Jurupa Hills. The lower limit is the channel of the Santa Ana River, inclusive, between Pedley Bridge and the U. S. Geological Survey gaging station at Prado. Attention is particularly drawn to other local uses of this term "Cucamonga Basin." It has been used to designate the gravel cone of Cucamonga Creek only. The term "Cucamonga Valley" has also been used for the entire valley from Pomona to Fontana. This, joined with Chino Basin, as sometimes used, would constitute "Cucamonga Basin" as used in this report.

Temescal Basin is the watershed of Temescal Creek, below Lake Elsinore exclusive, to the Santa Ana River exclusive between Pedley Bridge and the U. S. Geological Survey gaging station at Prado.

Lower Basin is the watershed of the Santa Ana River below U. S. Geological Survey gaging station at Prado; the watershed of Santiago Creek, the watershed of Newport Estuary and Carbon and Brea canyons, up to and terminating on the Los Angeles County line and the Pacific Ocean.

Yucaipa and Beaumont Subbasin of the Upper Basin comprise the watershed of San Timoteo Creek above its junction with Live Oak Canyon. This subbasin geologically and physically contains within itself features characteristic of the entire group. It contains mountain and foothill watersheds discharging into gravel storage, barriers between the gravels, rising water, and separated agricultural valleys. The waters escaping from this subbasin discharge into the main valley floor of Upper Basin.

In these basins, mountains, foothills and isolated hills are discussed principally in connection with hydrography, and water supply. The remainder, the valley floor, is generally the subject of the economic studies. The bulk of the unused agricultural land, the irrigated lands, the municipalities and the broad sandy stream beds are found in the valley floor.

The Maps Described. Much of the information collected has been placed on maps. This graphic representation is supplemented by tables under statistics.

The map "Basin Areas," Plate 1, facing page 12, portrays the position of the various basins referred to in this report.

Map 12, in pocket, "Index Map showing existing Reservoirs, Spreading Grounds and Reservoir Sites Surveyed," is an index map showing all reservoirs referred to in the text, or on which information of any kind has been obtained.

The map "Service Areas," Map 7, in pocket, represents the territory in which the various water organizations are distributing water or are understood to offer or are obligated to serve water, whether such lands are actually using water or not. The boundaries shown are necessarily generalized. It is frequently the case that two or more companies have consumers within the same area. In those cases the dominant use has been indicated and only one water organization shown for each area. The tabulation of total service area is thus free from duplication.

The map "Irrigated and Domestic Areas," 1927, Map 6, in pocket, shows the results of a field survey by this investigation in 1926-1928. The use which is predominatingly domestic has been shown with a separate symbol. The irrigated area shown in green includes certain areas of subirrigated cropped lands and pasture lands, near San Bernardino and in western Orange County.

The map "Drainage Areas," Map 4, in pocket, is an index map of the numerous sections into which the watershed was divided on account of position of gaging stations, or varying topographic character. This map is the reference for the intensive hydrography for the last two seasons in this report. It is intended to furnish a basis and guide for a future measurement program. Such a program is advisable in anticipation of flood and conservation works.

The map "Areal Geology," Map 14, in pocket, shows the Santa Ana Watershed, classified by nonabsorptive or granite areas, semiabsorptive or shale and sandstone areas, old alluvium or the earlier gravels elevated in places in benches and generally tighter, and the recent alluvium, the present gravel fill of the valleys, highly absorptive and generally the source of pumped water. This map is referred to in the geological article in this report.

Map 1, in pocket, "Santa Ana River," in six sheets, and Map 2, "Lytle Creek," on a scale of 2000 feet to one inch, show in detail the present course of these rivers. They are prepared from original surveys, or from reliable recent official surveys. The low water channel, the flood river bed, and the willow and cultivated areas adjacent are shown.

Map 13, in pocket, "Surveys of Reservoir Sites," in two sheets, records the results of all surveys of reservoirs made heretofore and of which there is record in this office. The surveys are presented simply as collected information, and for the purpose equally of assisting in elimination of nonfeasible sites as to indicate desirable sites.

Statistics. The general public statistical information available, and the condensed results of data collected by this investigation are assembled in the following tables:

TABLE 1. ASSESSED VALUATION 1927

Basin	San Bernardino County	Riverside County	Orange County	Los Angeles County	Total
Upper:					
Beaumont	0	$1,197,000	0	0	$1,197,000
Yucaipa	$678,000	335,000	0	0	1,013,000
Valley Floor	32,959,000	0	0	0	32,959,000
Jurupa	8,053,000	20,050,000	0	0	28,103,000
Cucamonga	22,458,000	1,800,000	0	$13,055,000	37,313,000
Temescal	0	6,311,000	0	0	6,311,000
Lower	0	0	$155,578,000	342,000	155,920,000
	$64,148,000	$29,693,000	$155,578,000	$13,397,000	$262,816,000

NOTE—These figures are compiled from detail reports by county auditors for 1927, by school districts. As the boundaries of school districts are not identical with basin boundaries, the distribution to basins is approximate.

TABLE 2. MOUNTAIN AND VALLEY WATERSHED OF SANTA ANA RIVER

In square miles

Basin	Mountain and foothill	Per cent	Valley floor	Per cent	Total
Upper	591	83	124	17	715
Jurupa	73	42	99	58	172
Cucamonga	103	28	269	72	372
Temescal	155	74	56	26	211
Lower	274	47	306	53	580
Totals	1,196	58	854	42	2,050

TABLE 3. HABITABLE AREA—BY BASINS

(In general, the valley floor, with the high valleys of Beaumont and Yucaipa included)
In acres

Basin	Present domestic area, 1927	Present irrigated area, 1927	River bed and waste	Future usable area	Total
Upper:					
Beaumont	500	3,900	200	4,160	8,760
Yucaipa	160	7,300	140	5,316	12,916
Main Valley	6,372	36,510	7,718	24,880	75,480
Jurupa	2,910	42,510	2,780	22,795	70,995
Cucamonga	3,280	98,776	4,944	69,504	176,504
Temescal	1,090	17,210	900	25,560	44,760
Lower	10,970	136,494	4,536	73,554	225,554
Totals	25,282	342,700	21,218	225,769	614,969

TABLE 3. (Continued). HABITABLE AREA BY COUNTIES

County	Acres	Square miles
San Bernardino	244,641	382
Riverside	117,796	184
Orange	215,268	337
Los Angeles	16,046	25
Totals	593,751	928

TABLE 4. IRRIGATED AND DOMESTIC AREAS AS OF 1927

In acres

(Refer to map 6 in pocket)

Basin	Within city boundaries		Outside city boundaries		Total
	Domestic	Irrigated	Domestic	Irrigated	
Upper:					
Main Valley	6,185	7,410	187	29,100	42,882
Yucaipa	0	0	160	7,300	7,460
Beaumont	500	400	0	3,500	4,400
Jurupa	2,690	17,890	220	24,620	45,420
Cucamonga	2,745	15,230	535	83,546	102,056
Temescal	1,040	6,600	50	10,610	18,300
Lower	10,485	11,890	485	124,604	147,464
Totals	23,645	59,420	1,637	283,280	367,982

TABLE 5. HISTORIC INCREASE IN AREAS USING WATER, 1888-1927

In acres

Year	Upper	Jurupa	Cucamonga	Temescal	Lower	Total	Authority
1888	10,100	12,450	12,900	750	23,500	59,700	Hall
1900	17,800						U. S. G. S.-W. S. P. 59
1902						70,492	U. S. Census
1904			20,500		30,700		U. S. G. S.-W. S. P. 139 142 and 219
1912	51,922	35,800	44,823	6,750	51,000	190,295	Conservation Commission
1919						185,508	U. S. Census
1927	54,742	45,420	102,056	18,300	147,464	367,982	S. A. Investigation

Hall—Wm. Ham. Hall, State Engineer, in "Irrigation in California," 1888—The figures given in the text, supplemented by additions from maps accompanying report for unlisted areas.

U. S. G. S. Water Supply Paper 59, Lippincott—The figures are taken from map of Irrigated Area accompanying paper for the year 1900. It covers the San Bernardino Quadrangle only.

U. S. Census—1920 Census Bulletin, Irrigation in California, "Area Irrigated by Drainage Basins, 1902 and 1919." Domestic areas are probably not included.

U. S. G. S. Water Supply Papers 138, 139, 142, and 219, Mendenhall—These papers published maps of Irrigated Area of San Bernardino and Redlands Quadrangles for year 1900, and Cucamonga, Pomona, Anaheim, Santa Ana, Downey, and Los Bolsas for year 1904-1905.

Conservation Commission—This report, published by State of California in 1912, contains statistical tables showing the irrigated areas for 1912 in Southern California, prepared by C. E. Tait.

Santa Ana Investigation—A complete field census of the irrigated lands was made in 1926, shown graphically on a map. This was supplemented by revisions and additions in 1927 and 1928. The figures are as of 1927, taken from this map; refer to map No. 6.

TABLE 6. CROP CLASSIFICATION, DOMESTIC AND IRRIGATED AREA AS OF 1927

In acres

County	Domestic	Citrus	Deciduous except as otherwise listed	Almonds apples cherries olives	Walnuts	Vines	Truck	Alfalfa	Field crops and unaccounted	Total map acreage
Upper Basin (valley floor, Yucaipa and Beaumont valleys):										
San Bernardino	6,532	19,901	1,925	6,972	21	871	------	------	13,210	49,432
Riverside	500	8	2,180	2,330	9	47	9	227	0	5 310
	7,032	19,909	4,105	9,302	30	918	9	227	13,210	54,742
Jurupa Basin:										
San Bernardino	220	13,485	1,437	798	208	562	------	------	------	16,710
Riverside	2,690	8,118	385	0	804	423	846	2,954	12,190	28,710
	2,910	21,903	1,822	798	1,012	985	846	2,954	12,190	45,420
Cucamonga Basin:										
San Bernardino	2,020	14,714	9,407	758	2,565	30,167	------	------	22,665	82,296
Riverside	0	0	1,140	0	376	1,450	1,540	1,440	7,604	13,550
Los Angeles	1,260	2,470	1,240	0	1,240	0	0	0	0	6,210
	3,280	17,184	11,787	758	4,181	31,617	1,540	1,440	30,269	102,056
Temescal Basin:										
Riverside	1,090	7,193	929	139	643	439	857	3,300	3,710	18,300
Lower Basin:										
Orange	10,970	51,900	1,555	550	15,400	250	5,700	3,000	58,139	147,464
Totals	25,282	118,089	20,198	11,517	21,266	34,209	8,952	10,921	117,518	367,982

TABLE 7. SERVICE AREA OF WATER ORGANIZATIONS AND INDIVIDUALS, 1927

In acres

Basin	Organized					Unorganized irrigation by individual owners	Total
	Domestic service	By diversion	By pumping	By diversion and pumping	Total organized		
Upper	11,200	17,300	7,500	4,500	40,500	17,600	58,100
Jurupa	4,100	6,700	8,300	14,600	33,700	12,300	46,000
Cucamonga	5,700	4,300	13,300	20,300	43,600	65,400	109,000
Temescal	1,000	2,700	5,700	6,900	16,300	3,100	19,400
Lower	23,100	31,900	2,400	0	57,400	108,700	166,100
Totals	45,100	62,900	37,200	46,300	191,500	207,100	398,600

Water Supply Originating Within Each Basin. Table 33, page 188, gives the hydrographic measurements and calculations to determine the supply and escape for the last two years, 1926-27 and 1927-28. These figures are given in detail for each area delineated on Map 4, in pocket. This Table 33 and Map 4, are published in complete detail in order to serve as a guide for future measurements.

Section 8, page 194, takes up in detail the theoretical restoration of the long period run-off for 34 years, beginning in 1894 when the first continuous measurements were begun. The basis of the restoration is stream flow. Rainfall is not used except as required for estimating the direct penetration of rainfall on the valley floor. The 34-year average rainfall is found to be 1 per cent less than a 50-year average, as given in "California Water Resources Investigation Bulletin No. 5," while a comparison of the run-off is found to be 4 per cent less. The 34-year period is selected as based on actual stream measurements, and as giving substantially a true long-period average.

The annual supply by basins is given for these 34 years in Table 35, page 200. Table 8 is a summary of Table 35, and shows 446,000 acre-feet as the average water supply of the watershed for the 34-year period, and 543,000 acre-feet as the average of the last 15 years.

This supply arises on widely spread areas, intercepted by gravel "sponges," and utilized on its way. It can never be considered as concentrated at one point in the Santa Ana River.

The most important variation here from former analyses, is the introduction of "basins," permitting the evaluation of figures for consumptive use and natural loss, and to determine the over-year storage in gravels by hydrographic considerations.

TABLE 8. SUMMARY OF ESTIMATED WATER SUPPLY ORIGINATING WITHIN EACH BASIN AS DETERMINED BY TABLE 35, PAGE 200

In acre-feet

This table includes the run-off and underflow from the foothill and mountain areas, together with the run-off and rainfall penetration on the valley floor.

Basin	34 year period (1894–1928)			15 year period (1913–1928)
	Maximum	Minimum	Average	Average
Upper	868,000	51,200	235,000	279,500
Jurupa	140,000	2,700	33,500	41,000
Cucamonga	304,000	11,800	93,300	113,900
Temescal	188,000	350	28,800	39,600
Lower	246,000	700	55,300	69,200
Totals	1,746,000	66,800	446,000	543,000

Input to Each Basin. The water supply originating in each basin as summarized in Table 8, and as given in detail in Table 35, page 200, is not necessarily utilized in that particular basin, but a portion of the water flows away through natural channels and underflow, or is exported by canals and pipe lines across the basin boundary into an adjoining basin. The actual accounting is shown in Table 9, page 101. This represents the average waters physically appearing in each successive basin, that is, the sum of waters originating locally, plus waters originating in adjoining basins yet flowing or diverted into the basin. Since some of the water is in transit through the basin and is again added to the total for each successive basin, the sum of the various "Inputs" would contain duplicated figures and would be meaningless.

TABLE 9. SUMMARY OF ESTIMATED INPUT TO EACH BASIN AS DETERMINED BY TABLE 36, PAGE 201

For 15 year period 1913-28—in acre-feet

The quantity of water physically accruing to each successive basin, being the sum of waters originating locally and waters originating above, yet entering the basin, including importations as of 1928.

Basin	Maximum	Minimum	Average 15-year period		
			Originating locally as in table 8	Entering from other basins	Total input
Upper	868,000	83,000	279,500	0	279,500
Jurupa	498,000	116,000	41,000	157,900	198,900
Cucamonga	647,000	78,700	113,900	120,200	234,100
Temescal	200,000	13,700	39,600	12,000	51,600
Lower	707,000	88,600	69,200	170,100	239,300

TABLE 10. ESTIMATED MEAN SUPPLY RETAINED WITHIN EACH BASIN AS DETERMINED BY TABLES 36 AND 37, PAGES 201 AND 202

For 15-year period 1913-1928

Basin	Mean input, acre-feet	Mean escape, acre-feet	Mean retained in basin, acre-feet
Upper	279,500	178,700	100,800
Jurupa	198,900	111,400	87,500
Cucamonga	234,100	155,600	78,500
Temescal	51,600	14,400	37,200
Lower	239,300	68,800	170,500
Total			474,500

Supply Retained Within Each Basin. By accounting hydrographically for the "Input" and the "Escape," basin by basin, "Supply Retained" in each basin has been determined in the last column of Table 10. This "Supply Retained" represents three quantities:

(a) The consumptive use or transpiration and evaporation of cropped areas and natural cover.

(b) The natural losses of stream beds and the moist lands adjoining, largely in willows and grasses.

(c) The water put into storage either in reservoirs or in gravels.

As will be seen later, surface reservoirs store only 5 per cent and the gravels 95 per cent of the water. In other words, the surface reservoir affects the matter so slightly that it may be considered that the storage in "Supply Retained" is practically all gravel storage. Tables 38 to 42, pages 202 to 204, under section 8, give the detailed calculation of each basin, year by year, for the last 15 years of consumptive use and natural losses and storage, which constitutes the quantity "Retained in Basin." "Mean Retained in Basin" over a series of years is a measure of the consumptive use and natural losses in each basin, depending for great exactness on how much the gravel storage had increased or decreased at the end of the period over the amount at its beginning. If the gravel storage were exactly the same in 1913 as in 1928, then the figure "Mean Retained in Basin" totaling 474,500 acre-feet represents with exactness the average consumptive use during the 15 years. If the amount in storage in 1913 were greater than in 1928, it would indicate that the consumptive use and natural losses were slightly greater than the "Mean Retained in Basin." If the amount in storage in 1913 were less than in 1928, it would indicate that the consumptive use and natural losses were slightly less. The word "slightly" is used because whatever this difference may have been, it affects conclusions as to consumptive use and natural losses by only 1/15 of such difference. This is because the average decrease or increase must be distributed over the 15-year period. Putting it in other words, if the base is made the years 1913 and 1928, the last column of Table 10, "Mean Retained in Basin," represents the average consumptive use and natural losses.

Maximum Gravel Storage Utilized. Adopting these figures so obtained for consumptive use and natural losses, it becomes possible to calculate year by year the amount which went into storage in that year, or was withdrawn. For instance, reference being made to Section 8, the first column and first line in Tables 36, 37 and 38, pages 201 to 202, in the season 1913-14, the "Input" to the Upper Basin from all sources was 352,000 acre-feet. The "Escape" was 165.000 acre-feet. The difference is the amount "Retained Annually in Basin," 187,000 acre-feet. As already indicated, the consumptive use and natural losses may be taken as 100,800 acre-feet. Subtracting this amount from "Retained Annually in Basin," an amount of 86,200 acre-feet still remains to be accounted for. This represents for that season that portion of the supply for that season which went into gravel storage. By successively accounting for the "Input" and "Escape" by years, a figure is arrived at for the amount put into gravel storage annually. In certain years, instead of a gain of storage, this calculation shows a decrease. It is now possible, by adding accumulatively the gain in storage and subtracting the decrease in storage, to find the accumulated gravel storage year by year above or below the base years. This calculation is illustrated in the last column of Tables 38 to 42, pages 202 to 204. Table 11 is a summary of these calculations and shows in the last column the total maximum reservoir and gravel storage which must have been utilized during the 15-year period over and above that existing in the base years. This Table 11 shows that the maximum storage in gravels for the valley floor of the entire Santa Ana River was 1,450,000 acre-feet. Bear Valley Reservoir and various smaller reservoirs have a maximum storage capacity of 74,000 acre-feet. The total storage in surface reservoirs and gravels is found to be 1,524,000 acre-feet. The surface storage is 5 per cent and gravel storage is 95 per cent of the total. The maximum storage was reached in the year 1916.

TABLE 11. ESTIMATED MAXIMUM RESERVOIR AND GRAVEL STORAGE UTILIZED IN EACH BASIN DURING THE PERIOD 1913 TO 1928

Based on Tables Nos. 38 to 42, Pages 202 to 204

In acre-feet

Basin	Maximum storage in gravels	Maximum existing surface storage	Total maximum reservoir and gravel storage utilized in last 15 years
Upper	514,400	71,000	585,400
Jurupa	114,200	1,000	115,200
Cucamonga	345,200	0	345,200
Temescal	126,000	1,000	127,000
Lower	349,700	1,000	350,700
Totals	1,449,500	74,000	1,523,500

Consumptive Use and Natural Losses. In section 5, page 158, the factors affecting summer consumptive use and natural losses are considered. Table 26, page 160, makes the analysis in detail. Table 12 is a condensed summary showing the consumptive use for the entire valley floor to be 381,000 acre-feet, and natural losses to be 93,500 acre-feet, a total of 474,500 acre-feet. Of the natural losses 14,500 acre-feet is assignable to river beds and marginal willows. The balance of natural loss is assigned to unirrigated moist lands, and unoccupied land.

Consumptive use is defined in this report as the sum of transpiration and evaporation incident to plant growth. Summer consumptive use has been found to vary from 1.67 acre-feet per acre for alfalfa down to .50 acre-feet per acre for vines. Bare river beds vary from zero where the water plane is deep, to 2.84 acre-feet per acre where the water is at the surface.

TABLE 12. SUMMARY OF ESTIMATED CONSUMPTIVE USE AND NATURAL LOSSES BY BASINS AS DETERMINED BY TABLE No. 26, PAGE 160

In acre-feet

This table of consumptive use is based on analysis of each basin by crops. Natural losses include the loss from free water surface, moist lands and unoccupied land.

Basin	Consumptive use	Natural losses	Total consumptive use and natural losses
Upper	57,396	43,404	100,800
Jurupa	63,276	24,224	87,500
Cucamonga	73,958	4,542	78,500
Temescal	24,516	12,684	37,200
Lower	161,887	8,613	170,500
Totals	381,033	93,467	474,500

Floods and Flood Control. Section 2, page 106, is devoted to flood control data. Historically, since 1841, floods of greater or less magnitude appear to have occurred in 16 years out of 87 years. The flood of 1862 apparently was the greatest of record.

Observations of peak floods and flood evidence, computed by Kutter formula, have been made on 41 streams on the Santa Ana River by this investigation, or by U. S. Geological Survey. On small mountain watersheds, the observations show apparent values for instantaneous peak of 1500 and even 2360 second-feet per square mile. For the greater areas, including portions of the valley floor, it is very much less. The main Santa Ana River at Prado, with a drainage area of 1471 square miles, appears to have reached only 29 second-feet per square mile in 1916, a year of severe flood.

The repose gradient, or the grade at which various sized materials appears to be deposited and come to rest during floods, is for boulders 2.8 per cent, gravel 1.8 per cent, and sand 0.2 per cent.

The velocity of water sufficient to cause transportation of boulders is probably between 15 and 25 feet per second. The velocity to transport sand is between 1 and 6 feet per second. At 6½ feet per second, scour has been found to take place. At 12 feet per second, the scour may carve out to a depth of 9 feet below the original bed. The transporting velocity of gravel is somewhere between these figures, 6 to 15 feet per second.

A comparison of the levels at various bridges indicates for the valley floor a building up of 5 feet in some portions of the channel, and a scour of 3½ feet. In general, it would appear that the larger boulders and gravel are deposited on the cones at the mouths of the canyons, and that sand and silt are conveyed clear through to the ocean.

The comparisons of levels show that Cajon Creek and Lower Lytle Creek have built up 1 foot in 21 years between Devore and San Bernardino. The Santa Ana River at E street bridge near San Bernardino has filled 5 feet. The Santa Ana River at U. S. Geological Survey gage at Prado in the lower canyon has lowered 3.4 feet in 9 years. The Santa Ana River at Talbert Bridge near the ocean has filled 5 feet.

Surface and Underground Reservoirs. In section 3, page 144, is given a catalogue of existing major reservoirs, aggregating 74,000 acre-feet capacity. Underground reservoirs have been studied under hydrography section 8, page 202, with the general result that the storage capacity now in use through a series of years is found to be 1,449,500 acre-feet.

Detailed cost estimates of 15 surface reservoirs, surveyed during the investigation in 1926, are given on pages 147 to 151.

Rainfall Penetration. In section 4, page 152, is given the preliminary report for rainfall penetration by Harry F. Blaney of the U. S. Department of Agriculture, with which this problem was taken up cooperatively. Rainfall penetration is defined as "the amount of rainfall reaching the ground water below the root zone." It is an important element in determining total water supply. For example in the season, 1926-1927, in the Cucamonga Basin, it accounts for 38 per cent of the water supply. The values are based on recent scientific observations and although preliminary are used confidently in this report along with stream gagings.

The findings are fully set out in section 4, page 152. In brief, it is found that the first rains in the fall are expended in restoring the "initial soil moisture deficiency." Transpiration on cropped areas as well as on areas of wild cover is also continuously depleting rainfall. Evaporation from the soil between storms is another source of loss. It is only after the descending excess moisture has passed the lowest root zone, that it can be held to have safely joined the ground water.

Absorption of Water and Spreading Works. In section 6, page 165, is given a digest of absorption information, including determinations by this investigation. All determinations have included the measuring of the actual wetted area. Absorption appears to vary from 0.2 second-feet per acre to 4.7 second-feet, or from 0.4 feet per day to 9.4 feet per day vertically.

A catalogue of existing spreading works is given. There are 13 spreading works now operating in the Santa Ana watershed, with a capacity of at least 200,000 acre-feet.

Underflow. In section 7, page 180, is published data on underflow and the corresponding Slichter Constant, which varies in this region from 0.15 to 3.42 cubic feet per minute, "transmitted through a cylinder of soil 1 foot in length and 1 foot in cross section under a head of 1 foot." One determination of underflow by the investigation is included.

Duty, Demand and Water Organizations. In section 9, page 216, is compiled the approximate duty of water for each basin, the monthly demand rate for water and a list of water organizations.

Rainfall. In section 10, page 222, the annual rainfall records for 1926–27 for 57 stations are given. Of these, 11 stations are U. S. Weather Bureau stations and the remainder are maintained privately.

Forestry. In section 11, page 223, the area and date of forest fires is given, and results of measuring run-off from a burned area.

Geology. In section 12, page 225, will be found the historic geology of the watershed, accounting for the great gravel storage beds. There is also appended the geology of the lower canyon of the Santa Ana River, in connection with studies for a dam site.

CHAPTER 2

FLOODS AND FLOOD CONTROL

Historical Flood Seasons. A collection has been made of information bearing on the recurrence of flood periods. An abnormally wet season does not necessarily yield a maximum flood. It appears probable that the flood of 1862 was the greatest flood of the known period. The references are from U. S. Geological Survey Water Supply Papers Nos. 426 and 447, Irrigation in California by Wm. Ham. Hall, State Engineer, and miscellaneous individual reports.

Year or season	*Type of year*	*Authority*
1786	Copious rainfall	U. S. G. S. No. 426 (Mission Fathers)
1811	Flood year	U. S. G. S. No. 426 (Mission Fathers)
1815	Flood year	U. S. G. S. No. 426 (Mission Fathers)
1825	Great flood, changed course of Santa Ana River	U. S. G. S. No. 426 (Mission Fathers)
1841–42	Wettest year ever known	U. S. G. S. No. 426 (Campbell)
1849–50	One of the wettest and most floody winters	U. S. G. S. No. 426 (Campbell)
1851–52	A severe flood year in southern California	U. S. G. S. No. 426 (Guinn)
1853	Big floods and snow	U. S. G. S. No. 426 (Campbell)
1861–62	"Before the flood of 1861-62, the lands on which this ditch (Aqua Mansa, between Colton and Riverside on North side) is used, were moist and rich bottom-lands, producing fine crops without irrigation and containing the residences of a flourishing settlement of native Californians. In that year the Santa Ana River swept these improvements away, and deposited a comparatively barren sand in place of the old fine soil."	Wm. Ham. Hall (page 288)
	"During the flood of 1862, Lytle Creek broke over from its course into Warm Creek, and ran down through what is now known as Lytle Creek wash, through the eastern part of Colton, and in doing so, destroyed a portion of the then new Meeks and Daley ditch. This creek continued to run in that course during the season; and in the following one, a ditch was constructed out from it, which supplied the Meeks and Daley ditch. But the latter ditch was reopened and used from Warm Creek in 1864."	Wm. Ham. Hall (page 284)
	"In 1862 it (Lake Elsinore) was high and probably overflowed."	U. S. G. S. No. 426 (page 71)
	"Santa Ana River at Anaheim ran 4 feet deep and spread in an unbroken sheet to Coyote Hills 3 miles beyond. It rained 30 days in succession beginning December 24 1861."	U. S. G. S. No. 426 (page 36)
	"The flood of 1862 covered the Santa Ana Cone (east of San Bernardino) with uprooted pines and cedars. This was a source of timber supply to the settlers for some years thereafter.'	Mr. Atwood. San Bernardino
1868–69	Flood year	Wm. Ham. Hall (page 262)
1884	Wet year	Wm. Ham. Hall (page 357)
1888–89	Flood in Lower Santa Ana Canyon	Wm. Ham. Hall (page 607)
1890–91	Floods noted in Lytle Creek and Upper Santa Ana River, February, 1891."	U. S. G. S. No. 447 (page 549)
	"Elsinore Lake overflowed heavily on February 22 and 23, 1891."	U. S. G. S. No. 447 (page 549)
1894–95	Flood in Lytle Creek December, 1894, overtopped Santa Fe R. R. trestle, between Rialto and San Bernardino	W. S. Post
1905–06	Wet season	U. S. G. S. Records
1906–07	Flood season	U. S. G. S. Records
1913–14	Flood on Lytle and Cajon creeks	U. S. G. S. No. 447 (page 548)
1914–15	Wet year	U. S. G. S. Records
1915–16	Flood year	U. S. G. S. No. 426
1921–22	Wet year	U. S. G. S. Records
1926–27	Flood year	U. S. G. S. Records

Flood Measurements. The floods actually measured are assembled in the following table. The principal authority is the U. S. Geological Survey, in Water Supply Papers No. 426 and No. 447. Estimates by others not supported by measurements, although published in these papers, are omitted here. This investigation has surveyed the flood evidences of 1927, and calculated the probable discharge by Kutter's formula on 30 streams. The coefficient "n" in Kutter's formula used varies from 0.025 to 0.050.

In this tabulation the peak discharge (or crest or instantaneous maximum) is given and the resulting rate of discharge per square mile. The 24-hour average peak is also shown when known.

TABLE 13. PEAK DISCHARGE OF SOUTHERN CALIFORNIA STREAMS IN SECOND-FEET

Stream and station	Drainage area, sq. mi.	Date	Value of "n" used	Peak discharge, second-feet	Peak discharge per sq. mi., second-feet	24 hour discharge, second-feet
Santa Ana River:						
at Mentone	189	Jan. 27, 1916	----------	29,100	154	----------
at Mentone	189	Feb. 16, 1927	----------	25,000	132	----------
E St. bridge, San Bernardino	515	Jan. 17, 1916	----------	40,000	78	----------
at Pedley bridge	888	Feb. 16, 1927	.030	15,400	18	----------
at Prado	1,471	Jan. 17, 1916	----------	43,000	29	----------
at Prado	1,471	Feb. 16, 1927	----------	18,000	12	16,000
at Santa Ana	1,629	Feb. 16, 1927	----------	25,000	15	13,000
Lytle Creek:						
at mouth of Canyon	39	Feb. 20, 1914	----------	14,700	377	8,300
at mouth of Canyon	39	Feb. 16, 1927	----------	5,300	135	1,370
at Foothill Blvd.	137	Feb. 21, 1914	----------	16,000	117	3,000
at San Bernardino	137	Jan. 18, 1916	----------	16,000	117	6,640
Cajon Creek:						
at Glen Helen Ranch	74	Feb. 21, 1914	----------	8,360	113	2,200
at Keenbrook	42	Dec. 20, 1921	----------	5,000	119	1,150
at Keenbrook	42	Feb. 16, 1927	----------	950	23	369
Lone Pine Creek:						
at Keenbrook	17	Dec. 19, 1921	----------	810	48	91
San Antonio Creek:						
near Claremont	17	Dec. 19, 1921	----------	1,020	60	262
at power house No. 1 bridge	25	Feb. 16, 1927	.050	3,150	126	----------
Cucamonga Canyon:						
near Upland	10	Feb. 16, 1927	.050	6,120	612	----------
Deer Canyon:						
near Cucamonga	3.5	Feb. 16, 1927	.050	5,225	1,490	----------
Day Canyon:						
near Etiwanda	4.9	Feb. 16, 1927	.050	4,430	905	----------
East Etiwanda:						
near Etiwanda	2.9	Feb. 16, 1927	.050	2,840	980	----------
Ingvaldsen Canyon						
near Fontana	1.1	Feb. 16, 1927	.040	765	694	----------
San Sevaine Canyon:						
near Fontana	1.8	Feb. 16, 1927	.040	2,540	1,440	----------
Hawker Canyon:						
near Fontana	.5	Feb. 16, 1927	.035	370	740	----------
Howard Canyon:						
near Fontana	.7	Feb. 16, 1927	.035	925	1,320	----------
Calwell Creek:						
near Keenbrook	1.7	Feb. 16, 1927	.035	460	270	----------
Kimbark Creek:						
near Devore Heights	1.2	Feb. 16, 1927	.035	360	300	----------
East Kimbark Creek:						
near Devore Heights	.9	Feb. 16, 1927	.035	230	256	----------
Ames Canyon:						
near Devore	1.0	Feb. 16, 1927	.030	330	330	----------
Cable Canyon:						
west of Devil's Canyon	2.7	Feb. 16, 1927	.035	285	106	----------
Devils Canyon:						
near San Bernardino	6.3	Jan. 2, 1922	----------	111	18	63
near San Bernardino	6.3	Feb. 16, 1927	----------	182	27	110
Waterman Canyon:						
near Arrowhead Springs	4.5	Jan. 2, 1922	----------	164	36	87
near Arrowhead Springs	4.5	Feb. 16, 1927	----------	87	19	65
Strawberry Creek:						
near Arrowhead Springs	9.2	Jan. 2, 1922	----------	408	44	208
near Arrowhead Springs	9.2	Feb. 16, 1927	----------	380	41	265
Little Sand Creek:						
near Patton	1.2	Feb. 16, 1927	.040	2,855	2,360	----------
Sand Creek:						
near Patton	3.1	Feb. 16, 1927	.040	1,620	522	----------
City Creek:						
near Highland	19.8	Mar. 14, 1921	----------	1,320	67	393
near Highland	19.8	Feb. 16, 1927	----------	1,930	97	1,200
Reservoir Canyon:						
near East Highland	1.1	Feb. 16, 1927	.035	275	250	----------
East Highlands:						
near East Highland	1.2	Feb. 16, 1927	.035	380	316	----------
Plunge Creek:						
near East Highland	16.8	Mar. 14, 1921	----------	1,100	66	427
near East Highland	16.8	Feb. 16, 1927	----------	1,420	84	965
Oak Canyon:						
west of Santa Ana Canyon	2.2	Feb. 16, 1927	.050	1,570	710	----------
Morton Canyon:						
northeast of Mentone	2.2	Feb. 16, 1927	.035	250	114	----------
Spoor Canyon:						
near Yucaipa Gateway	1.2	Feb. 16, 1927	.040	880	734	----------

TABLE 13. PEAK DISCHARGE OF SOUTHERN CALIFORNIA STREAMS IN SECOND-FEET—Continued

Stream and station	Drainage area, sq. mi.	Date	Value of "n" used	Peak discharge, second-feet	Peak discharge per sq. mi., second-feet	24 hour discharge, second,feet
San Timoteo:						
near Redlands	120 0	Feb. 16, 1927		3,000	25	1,840
Warm Creek:						
near Colton		Dec. 21, 1921		2,780		835
near Colton		Feb. 16, 1927		2,140		1,290
Box Springs Canyon:						
near Riverside	3 6	Feb. 16, 1927	.030	65	18	
Sycamore Canyon:						
near Riverside	9 5	Feb. 16, 1927	.030	525	55	
Unnamed Canyon:						
near Riverside	7 3	Feb. 16, 1927	.030	225	31	
Mockingbird Canyon:						
near Arlington	10 5	Feb. 16, 1927	.025	300	29	
Santiago Creek:						
near Villa Park	86 0	Feb. 16, 1927		11,000	128	7,000
Mill Creek:						
near Craftonville	44 0	Feb. 16, 1927		4,500	102	1,690
Temescal Creek:						
near Corona	115 8	Feb. 16, 1927	.050	7,500	48	
Chino Creek:						
near Chino		Feb. 16, 1927	.040	1,270		
Reche Canyon:						
near Redlands	11.6	Jan. 17, 1916	.025	370	32	
San Gabriel River:						
below mouth of Rogers Canyon	227 0	Feb. , 1914		26,700	117	
near Azusa	222 0	Jan. 18, 1916		40,000	180	22,300
San Jacinto River:						
South Fork at Hemet Reservoir	67 0	Jan. 27, 1916		9,550	145	
South Fork at Hemet Reservoir	67 0	Feb. , 1927		25,000	374	
near San Jacinto	141 0	Jan. , 1916		30,000	213	
near San Jacinto	141.0	Feb. , 1927		44,600	316	

FIG. 1—Sawpit Canyon near Monrovia, April 7, 1925. A flood of 1000 second-feet.

FIG. 2—San Dieguito River near San Diego. Spillway of Lake Hodges, flood of 10,000 second-feet.

Flooded Areas. The channel of the Santa Ana and its principal tributaries have been mapped by the investigation with special reference to the width and marginal character of the banks. A field survey was made of the extent of the 1927 flood where flood marks could be ascertained, and information obtained elsewhere from those acquainted with the conditions. Table 14 gives the results of these surveys. The portion of the river and its branches where flow continues throughout the year covers an area of 512 acres. The total natural river bed is 6278 acres. The area covered by the 1927 flood is 6368 acres. This 1927 flooded area is delineated on Map 3, in pocket.

TABLE 14. FLOODED AREAS IN VALLEY FLOOR

In acres

Basin	Perennial flow	Total natural wet and dry river bed	Total covered by flood of 1927
Upper	26	2,688	2,003
Jurupa	65	672	1,145
Cucamonga	308	806	1,559
Temescal	0	770	191
Lower	113	1,342	1,470
Totals	512	6,278	6,368

Transportation of Debris. The gradient on which various sized material carried by floods is deposited, and the gradient at which it is transported have been analyzed from the profile of three principal streams, as shown in Table 15-A. This table indicates that:

Boulders will be transported in channels with a gradient of 3.3 per cent to 3.8 per cent or greater. The gradient of the channels of the streams in San Bernardino Mountains generally exceeds 3.3 per cent, and reaches 8 per cent and 10 per cent. These channels may be expected to transport debris in flood period. Boulders are found to come to repose in the gravel cones on gradients of 2.4 per cent to 3.8 per cent.

Gravel appears to be transported on grades of 2.4 per cent to 2.8 per cent or over. It appears to come to repose on gradients of 1.4 per cent to 2.0 per cent.

Sand appears to be kept in motion on gradients of 0.3 per cent to 0.4 per cent or over. It tends to settle on gradients of 0.2 per cent.

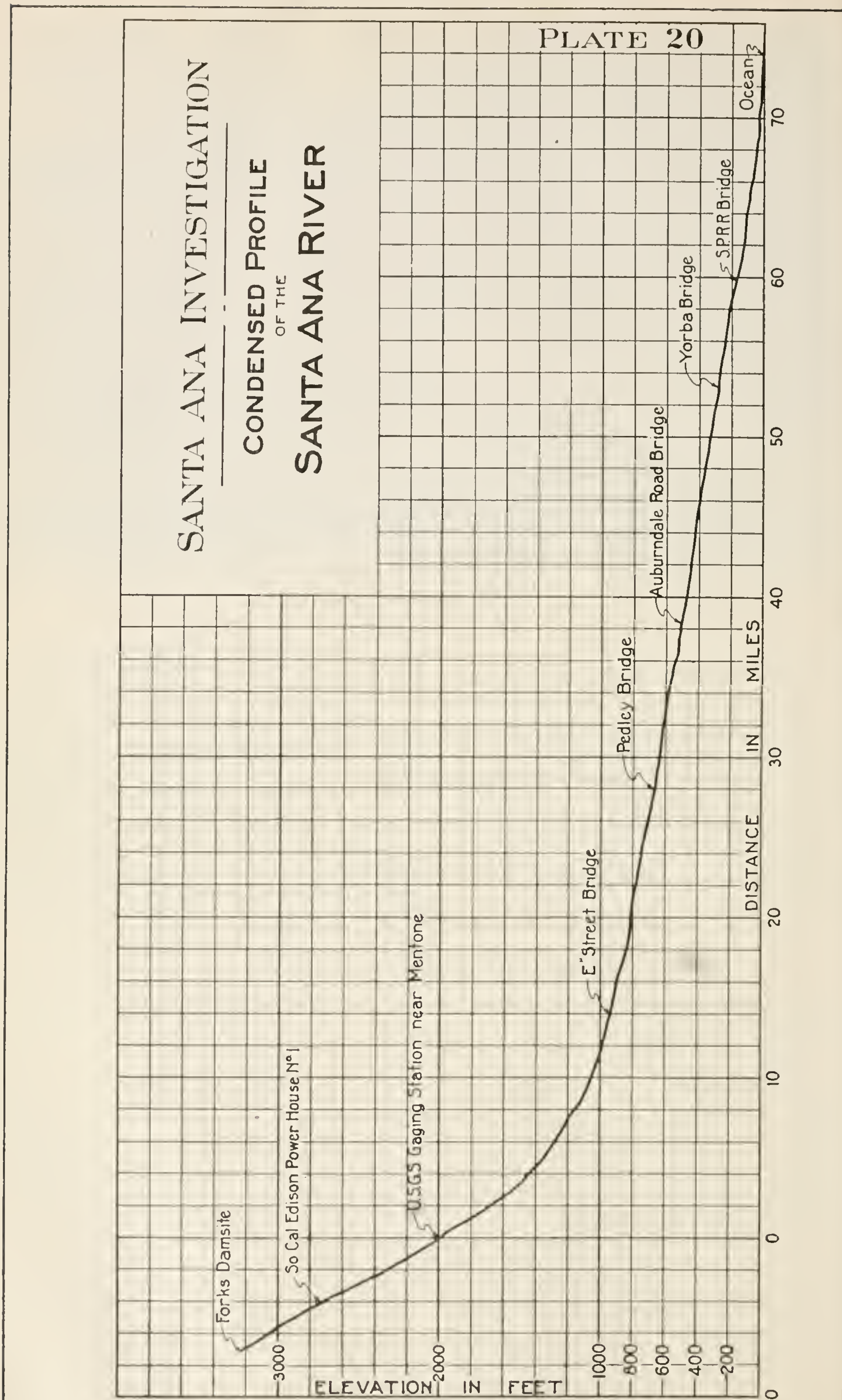
PLATE 20
SANTA ANA INVESTIGATION
CONDENSED PROFILE
OF THE
SANTA ANA RIVER
Forks Damsite
So Cal Edison Power House No 1
U.S.G.S Gaging Station near Mentone
E" Street Bridge
Pedley Bridge
Auburndale Road Bridge
Yorba Bridge
S.P.R.R. Bridge
Ocean
3000
2000
1000
800
600
400
200
ELEVATION IN FEET
10
0
10
20
30
40
50
60
70
DISTANCE IN MILES

TABLE 15-A. REPOSE GRADIENT AND SCOURING GRADIENT FOR CHANNEL MATERIAL OF TYPICAL LARGER STREAMS IN SANTA ANA WATERSHED

Santa Ana

Character of channel	Grade, per cent	Coarser material	Material comes to repose at gradient of, per cent	Material scours at gradient of, per cent
Mountain, lower portion before leaving canyon	3.3	Boulders		3.3
Gravel cone	2.8	Boulders	2.8	
Gravel cone	2.8	Gravel		2.8
Valley floor	1.8	Gravel	1.8	
Opposite Redlands	1.8	Sand		1.8
Orange street (Redlands) to Tippecanoe bridge	1.0	Sand		1.0
Colton to Lower Santa Ana Canyon	.4 to .3	Sand		.3 to .4
Yorba bridge to Talbert bridge	.3	Sand		.3
Talbert bridge to ocean	.2	Sand	.2	.2

Lytle Creek

Mountain, lowest part of canyon	3.3	Boulders		3.3
Spreading dam to junction Cajon Creek	2.4	Boulders	2.4	
Spreading dam to junction Cajon Creek	2.1	Gravel		2.4
Junction Cajon Creek to Mt. Vernon avenue	1.4 to 1.1	Gravel	1.4	
Junction Cajon Creek to Mt. Vernon avenue	1.4 to 1.1	Sand		1.4
Mt. Vernon avenue to junction Santa Ana River via Warm Creek	.7	Sand		.7

San Antonio Creek

Mountain, lower canyon	5.7	Boulders		5.7
Gravel cone	4.5	Boulders		4.5
Gravel cone	3.8	Boulders	3.8	
Gravel cone	3.8	Gravel		3.8
Gravel cone	2.0	Gravel	2.0	
Gravel cone	2.0	Sand		2.0
Valley floor	1.0	Sand		1.0
Chino to junction Santa Ana River	.4	Sand		.4

The solids transported by water for an entire season or for several seasons, including the occasional storms, has been determined for the Sweetwater River at Sweetwater Reservoir and the Arroyo Seco at Devil's Gate Flood Control Reservoir. These show the solids to be 0.1 per cent and 0.3 per cent, respectively, of the total amount of water flowing. The Sweetwater Reservoir is at the mouth of a long stream, and Devil's Gate Reservoir is at the base of a gravel cone.

The solids transported by water from burned-over watersheds have been determined during floods on Sawpit Canyon near Monrovia, Rogers Canyon near Azusa, Fish Canyon near Duarte, and Barranca near Devil's Canyon. The results vary from 15 per cent to 54 per cent solids to water, during storm conditions. Of the solids in these observations, from one-half to three-quarters is ash.

The velocity required to produce transportation in large quantity appears to be over 6 feet per second as found in the Los Angeles River near its mouth.

The following observations have been collected:

TABLE 15-B. SILT AND DEBRIS TRANSPORTATION DURING FLOODS

Stream or structure	Authority	Size of coarsest material transported	Velocity of water in feet per second	Per cent of solids transported during storm by volume	Per cent of solids transported to run-off by volume
St. Francis dam failure March 12, 1928	Los Angeles flood control	Large section of dam	93		
St. Francis dam, "several thousand feet downstream"	Report State Commission	10,000 ton fragments			
St. Francis dam, 1.5 miles downstream	Report State Commission		18		
San Jacinto River	W. S. Post and U. S. G. S.	10 yard concrete block	18		
Sawpitt Canyon, flood of April, 1925	H. C. Troxell	Boulder 3 feet dia. landed on deck of bridge.	25		
La Grange Flume, Trinity County	W. S. Post	Boulders 2 feet dia.	10 to 15		6.
Sand and dredging pumps	Commercial design	Sand and mud	12		10.
Los Angeles River, Willow street bridge. Observation for "Critical velocity where scour begins." Scour begins at 6.5 feet p.s. Scour 9 feet depth at 12 feet p.s.	Pasadena water department	Gravel, sand and silt	6.5 to 12		
Devils Gate reservoir, capacity 6503 acre feet, 1921-27	Pasadena Water Department	Gravel			.3
Zuni dam, New Mexico, original capacity 10,230 acre-feet in 1906	Trans. A. S. C. E. Aug., 1928, Robinson	Volcanic sand and clay			2.6 to 19.
Elephant Butte, New Mexico	Trans. A. S. C. E. April, 1928, Lawson				1.6
Barranca at Devils Canyon, San Bernardino County, Feb. 4, 1928	Forest service	Gravel and sand		17.	
Sweetwater reservoir, San Diego County	U. S. G. S. Annual report 1895-96, Schuyler	Sand			.1
American River near Fairoaks	U. S. G. S. W. S. P. 274				.0015 to .0106
Owens River at Round Valley	U. S. G. S. W. S. P. 274				.0006 to .0176
Owens River at intake Los Angeles aqueduct	U. S. G. S. W. S. P. 274				.0032 to .0156
Pit River near Bieber	U. S. G. S. W. S. P. 274				.0015 to .0191
Putah Creek near Winters	U. S. G. S. W. S. P. 274				.0025 to .0854
Sacramento River near Red Bluff	U. S. G. S. W. S. P. 274				.0006 to .0216
Sawpit Canyon near Monrovia—					
Dec. 16, 1924	U. S. G. S.	Fine sand and ash		40.	
April 4, 1925	U. S. G. S.	Fine sand and ash		54.	
Rogers Creek near Azusa—					
Dec. 16, 1924	U. S. G. S.	Fine sand and ash		48.	
Mar. 6, 1925	U. S. G. S.	Fine sand and ash		42.	
Mar. 29, 1925	U. S. G. S.	Fine sand and ash		39.	
April 4, 1925	U. S. G. S.	Fine sand and ash		40.	
April 20, 1925	U. S. G. S.	Fine sand and ash		18.	
Fish Creek near Duarte—					
Dec. 16, 1924	U. S. G. S.	Fine sand and ash		16.	
Mar. 31, 1925	U. S. G. S.	Fine sand and ash		16.	

San Gabriel River—					
Mar. 31, 1925 at Whittier blvd.	San Gabriel Investigation	Fine sand and silt		.009	
Mar. 31, 1925 at Telegraph road	San Gabriel Investigation	Fine sand and silt		.045	
Mar. 31, 1925 at Artesia road	San Gabriel Investigation	Fine sand and silt		.085	
April 7, 1926 at U. S. G. S. Station	U. S. G. S.			5.48	
Nov. 26, 1926 at U. S. G. S. Station	San Gabriel Investigation			.498	
Dec. 28, 1926 at U. S. G. S. Station	San Gabriel Investigation			.029	
Dec. 28, 1926 at Foothill blvd.	San Gabriel Investigation			.160	
Dec. 28, 1926 at northwest line	San Gabriel Investigation			.062	
Dec. 29, 1926 at Foothill blvd.	San Gabriel Investigation			.141	
Dec. 29, 1926 at northwest line	San Gabriel Investigation			.100	

NOTE—The samples for Sawpit, Rogers, and Fish creeks were collected by U. S. Geological Survey, and those on San Gabriel River by San Gabriel Investigation. The laboratory tests were made by H. C. Troxell, Santa Ana Investigation. In Sawpit Canyon the volume of dry solids were in the proportion of fine sand 27 per cent and ash 73 per cent on December 16, 1924; and on April 4, 1925, 56 per cent and 44 per cent respectively.

On Rogers Creek the fine sand varied from 47 per cent to 72 per cent of the total solids, the remainder being ash.

FIG. 3—Hansen Canyon, tributary of Big Tujunga Canyon, near Sunland. Erosion on banks after fire December 23, 1919.

FIG. 4—Sawpit Canyon near Monrovia. Rock transported onto bridge by flood of April 7, 1925.

FIG. 5—Slide Peak in Bear Creek, branch of Santa Ana Canyon, source of debris shown in foreground.

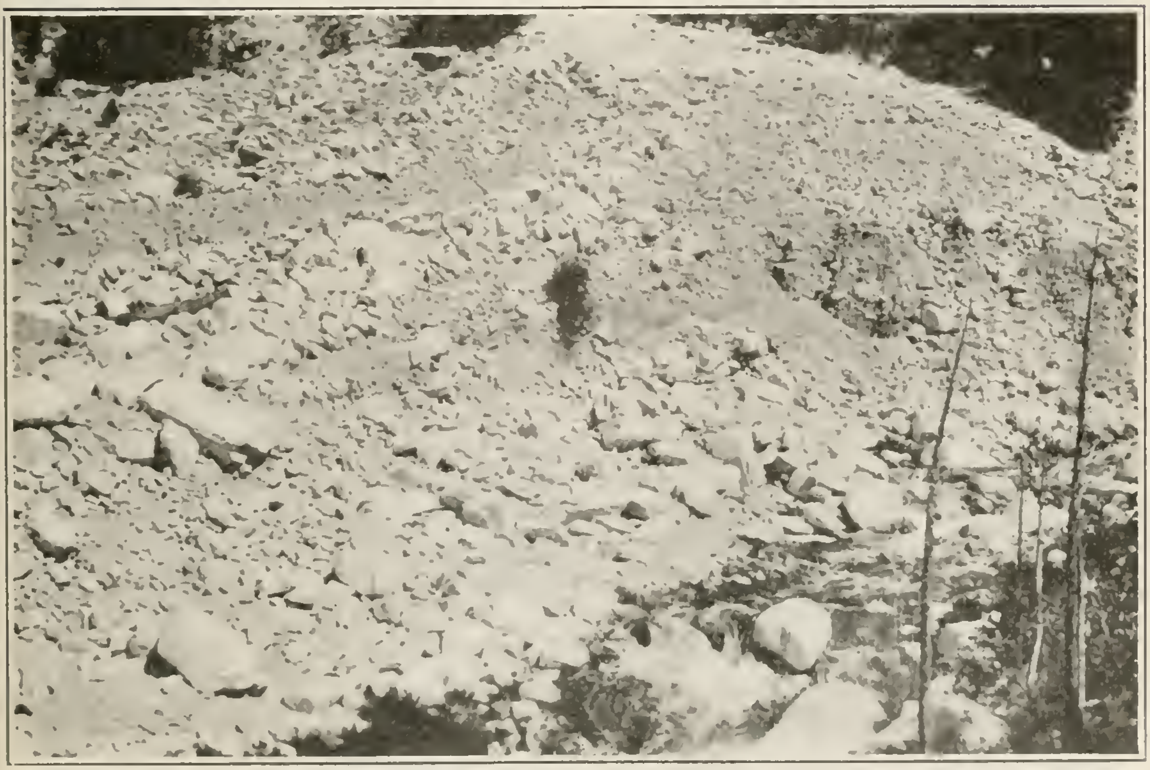

FIG. 6—Remnant of natural dam on Bear Creek at former Slide Lake, caused by debris carried by Slide Creek, a side canyon. The dam was washed out by flood of February, 1927.

STATE OF THE ART OF FLOOD CONTROL*

Various destructive floods have taken their toll in Los Angeles County, and ever since any records have been kept, the toll has become greater with each succeeding flood because of the increased value of the lands and later developments.

Following the destructive floods of 1914, a board of engineers was appointed by the board of supervisors on April 3, 1914, "charged with the task of formulating plans for works to control and render harmless the floods of Los Angeles County."

According to their provisional report of June 3, 1914, the direct physical damage done by the 1914 flood was $7,600,000, not including damage to navigable waters. In their provisional report they also stated that from the past records another disastrous flood might come again within two years. Their prediction was well justified for in 1916 another destructive flood visited Los Angeles County which did as great damage as did the one of 1914.

It was during the progress of the work of the Board of Engineers that the Los Angeles County Flood Control District was created by act of the California legislature approved June 12, 1915 (Stats. 1915, page 1502) "to provide for the control of the flood and storm waters of said district, and to conserve such waters for beneficial and useful purposes by spreading, storing, retaining or causing to percolate into the soil within said district, or to save or conserve in any manner, all or any of such waters, and to protect from damage from such floods or storm waters the harbors, waterways, public highways and property in said district."

This is in process of accomplishment by various methods, depending on the location, quantity of storm water involved and the topography and geology of the country. In general, however, concrete or earth-fill dams have been used wherever adequate reservoir sites were available, check dams in the mountains and foothill areas, diversion weirs for spreading on the gravel cones and channel straightening and channel protection in the low lands and desilting basins below the headwaters of the smaller streams.

Storage Dams. The following dams have been completed, or are under construction and are used for the control of floods as well as the conservation of water.

Name	Location	Type	Height above stream bed, feet	Capacity in acre-feet
Pacoima	Pacoima Canyon	Constant angle	365	9,400
Devil's Gate	Arroyo Seco	Arched gravity	100	6,503
Big Santa Anita	Big Santa Anita Canyon	Constant angle	200	1,580
Sawpit	Sawpit Canyon	Constant radius arch	160	634
Big Dalton	Big Dalton Canyon	Multiple arch	160	1,538
San Dimas	San Dimas Canyon	Arched gravity	95	1,820
Live Oak	Live Oak Canyon	Arched gravity	70	282
Thompson	Thompson Creek	Rock and earth fill	80	1,024
Puddingstone 1	Puddingstone Creek, near San Dimas	Rolled earth fill	140	
Puddingstone 2	Puddingstone Creek, near San Dimas	Rolled earth fill	56	20,012
Puddingstone 3	Puddingstone Creek, near San Dimas	Rolled earth fill	44	
Sierra Madre	Little Santa Anita Canyon	Constant radius arch	60	150,000 cu. yards debris

*As illustrated by the experience of Los Angeles County Flood Control District and contributed by E. C. Eaton, Chief Engineer.

All of the above mentioned dams except Puddingstone are to control floods directly from the watersheds above them as well as store water when possible for irrigation or spreading later in the season. The Puddingstone Reservoir, which is filled by means of a flood canal, not only controls the flow of waters above the reservoir site but is connected by a concrete flume of 3500 second-feet capacity with San Dimas Canyon, so that waters released from the San Dimas Reservoir can be diverted to the Puddingstone Reservoir, and so be stored for future use. By diverting the surplus waters from the San Dimas Reservoir through the flume to the Puddingstone Reservoir, the annual maintenance costs on the San Dimas wash are also greatly reduced.

It was at one time proposed to construct a concrete lined tunnel about three and one-half miles in length from Cattle Canyon near Camp Bonita in the San Gabriel watershed, to the San Dimas Canyon about two miles above the San Dimas Dam. Thus surplus water could be diverted via San Dimas Canyon to the Puddingstone Reservoir for storage and use in the San Gabriel Valley. To date this has not proved feasible due to water right complications.

The ultimate program includes the building of several other dams in other canyons, the largest of which is the San Gabriel Dam located at the forks of the canyon above Azusa and for which purpose bonds to the amount of $25,000,000 were voted in 1924. This dam would regulate and conserve the waters from the largest single watershed in the district and would protect the cities and agricultural lands between the mouth of the canyon and the ocean at Long Beach from flood damages.

Had Devil's Gate Dam been built at the time of the storms of 1915, computation shows that the instantaneous peak of 3500 second-feet occurring in January, 1915, would have been reduced to 450 second-feet, and the February instantaneous peak of 3690 second-feet would have been reduced to 1836 second-feet. For a storm of April 5, 1926, actual operation shows a reduction of the instantaneous peak from 1400 second-feet to 200 second-feet.

The cost of flood control reservoirs already constructed by the Los Angeles County Flood Control District varies from $70 per acre-foot of capacity to over $500 per acre-foot, the latter in a few instances of small reservoirs.

Check Dam. The earlier check dams built by the district were constructed of materials found convenient to the particular site, and were built in rubble formation with little or no interlocking or tieing together of the various units. These would not stand up under flood conditions and soon went to pieces. The later check dams have either been of more flexible construction, using rock walls and aprons tied together with mesh wire, or rigid construction in the form of concrete dams for storage of debris such as the Sierra Madre Dam.

The sizes of the check dams built has varied, depending on local conditions in the various canyons, but on an average they are about 4 feet 6 inches high by 35 feet long.

Several hundred check dams have been built in the following canyons: Wilson, Pacoima, Haynes, Loope, Dunsmuir, Pickens, Rubio, Eaton, Sawpit, San Gabriel, Little Dalton, San Dimas, Live Oak, Thompson and Williams.

The cross-section adopted for wire-bound rock walls is:

(a) Base approximately equal to height.

(b) Downstream face vertical.

(c) Upstream face stepped by 8-inch rise and 8-inch offset.

(d) Top width 2 feet.

(e) Mattress downstream 4 to 8 inches thick, 5 feet wide, for 5 feet height and increased proportionately.

The cost of building check dams varies greatly with location, ease of access and supply of material. Average cost of various structures are given later.

Check dam construction by Los Angeles County Flood Control is illustrated by pictures in Pickens Canyon. Fig. 7, page 124, shows the third and fourth dams above footbridge near White's Place. Fig. 8, page 124, the first and second dams above the same point.

Diversion Weirs. Diversion weirs have been constructed on the San Antonio wash, which divert the waters from the main flood channel and spread them over the cone above Foothill boulevard. By this method all ordinary flows and minor floods are absorbed by the gravels, and only the larger floods pass Foothill boulevard. The spreading over the cone is accomplished by running the waters through several different channels and is controlled by wire-bound walls or mats placed on advantageous lines and which would return any excess flow to the main channel again.

In San Antonio wash, the Pomona Valley Protective Association has acquired some 1008 acres of land on which have been constructed 7 miles of steam shovel cut ditches and 10 miles of small spreading ditches. (See Plate 4, page 164.) It is expected that in excess of 320 second-feet may be spread with this system which cost about $22,000. Adequate spreading ditches can be built at cost of from $20 to $50 per acre.

Channel Control. Channel control has been obtained by:

(a) Concrete lined channels, through highly developed properties on small streams.

(b) Double or single rows of boiler tubing or iron pipes driven vertically, covered with mesh wire. The space behind is filled with brush, orchard cuttings or other debris.

(c) Double or single rows of wooden piling covered with mesh wire. The space behind filled with brush.

(d) Earth levees protected by rock riprap.

(e) Rock wall mattress levees. These levees are interlaced and bound with mesh wire. The front slope is about 1 to 1, and the height is equal to the base. The wall is built up to the required height by successive layers of hand-laid rock and boulders enclosed in mesh wire and tied together mattress fashion. Attached to the front toe of the wall is an apron, a single mattress layer built in the same manner and extending into the channel. The thickness of the apron varies from 4 to 12 inches.

In theory the pipe and wire type permits the water to pass through the protective work to an area of still water, where it deposits its load of silt. The swifter moving water passes on in the channel.

The single row of boiler tubing and wire mesh construction is illustrated in Fig. 9, page 125. This is located at the junction of San Dimas and Big Dalton wash in the San Gabriel Valley.

Piling and wire mesh construction is illustrated by Fig. 11 and Fig. 12, page 126.

Rock wall mattress construction is illustrated by Fig. 10, page 125. This is located 500 feet south of Foothill Boulevard Bridge over the San Gabriel. In practice whenever scour takes place, the apron being flexible drops down and prevents the scour extending under the wall. Fig. 13 and Fig. 14, page 127, illustrate a case on the San Gabriel River north of Foothill Boulevard Bridge. Here the apron was not wide enough and scouring extended until the main wall was undermined, causing the wall to turn completely over. But in overturning it held together as shown in Fig. 15, page 128, and continued to protect the bank. Fig. 16, page 128, is of the same region.

Protection of the lower San Gabriel and Los Angeles rivers has been accomplished by levee embankments protected by riprap. Fig. 17 and Fig. 18, page 129, illustrate the works on the Long Beach channel near Anaheim Street Bridge. Fig. 19 and Fig. 20, page 130, illustrate the works on Los Angeles River at Workman Station.

Scour and Silt. The Pasadena Water Department had taken measurements at the Willow Street Bridge over the Los Angeles River where the river bed consists of sand and silt, as well as on the Lexington wash where the bed consists of rocks and gravel, relative to the critical velocity at which scour begins. They found that for velocities under 6 to 6½ feet per second no scour took place, but above that velocity the depth of scour increased by a direct ratio. At a velocity of 12 feet per second at the Willow Street Bridge 9 to 10 feet of scouring had taken place. About the only difference between the two locations at which the measurements were taken was that on the decrease of velocity the sand and silt was held in suspension longer than the coarser gravels.

The Water Department also took measurements at the Devil's Gate Reservoir in the fall of 1927 to determine the amount of silt deposited since the construction of the Devil's Gate Dam in 1920 and 1921. It was found that near the dam the silt had been deposited in layers to a depth of about 5 feet and then tapering to zero in other parts of the reservoir. It was estimated that 140 acre-feet of silt had been deposited. The Water Department records also show that 41,738 acre-feet of water has entered the reservoir during the same period, making the silt burden only one-third of one per cent. This period, however, has been the dry cycle and only in 1922 did any great amount of water flow into the reservoir, when over half of the total entered the reservoir.

The pipe and wire work is temporary, having a life of 3 to 5 years and is used on the smaller washes. The piling and wire, also of a temporary nature, having a life of about 7 years, is used on the larger streams. With the lack of bond funds on the major number of our streams it is, however, impossible to finance the more desirable permanent work, although the capitalized value of the maintenance and replacements on the temporary works over a period of 10 to 20 years would amply warrant the more permanent concrete or protected levee construction.

Costs. The following are actual costs from the 1927 construction program of the Los Angeles County Flood Control District. With the exception of the pipe and wire, piling and wire, and rock and wire mats which are put in by district forces, the prices are for contract work to which has been added the cement and reinforcing steel supplied by the district.

Wire and Rock Mattress. This type of construction is used on the larger streams and rivers where a flexible mat is required. They are generally placed on levees of gravel or on cut banks in gravel material.

Receding flood flows cause undercutting and the flexible mat will settle into place, forming a cutoff.

Two types are in general use, 4 inches thick and 8 inches thick. The following are costs:

Four-inch mat, including all materials and surfacing of bank, per square foot, 20 cents.

Eight-inch mat, per square foot, 30 cents.

This type of construction may be classed along with the more permanent classes, although its life is limited by the life of the exposed wire. Figs. 22 and 23, pages 131 and 132, illustrate this construction.

Pipe and Wire. This consists of second-hand boiler tubing driven with sledges upon which wire netting is fastened. In the double type the space between the netting is filled with brush. This is a temporary type of construction. Fig. 24, page 132, shows an example. The costs are:

Single row, 58-inch height, per lineal foot, one side, 40 cents.
Single row, 84-inch height, per lineal foot, one side, 45 cents.
Double row, 58-inch height, per lineal foot, one side, 70 cents.
Double row, 84-inch height, per lineal foot, one side, 80 cents.

Piling and Wire. This is used on the larger streams and is also a temporary type of construction. The costs are:

Single fencing, 116-inch height, type I Ellwood fencing poultry netting, piles spaced 10-foot centers, per lineal foot, $2.

Double fencing, 116-inch height, with front fence of Ellwood fencing and poultry netting in rear, per lineal foot, $2.25.

The above is for 10-foot staggered spacing of piles or 10-foot centers along a single fence. The costs are exclusive of channel excavation work. Examples of this are shown on Figs. 25 and 26, page 133.

Check Dams. The average cost of these run about $6.50 per cubic yard of material, ranging from a minimum of $6 in easy to $10 in the more inaccessible locations. Figs. 27 and 28, page 134, show types of construction.

Large Concrete Channels. An example of this type is the Puddingstone diversion channel constructed in the summer of 1927. Its grade varies from 1.086 per cent to 1.632 per cent. It is a concrete rectangular section 14 feet wide with 10-foot 6-inch walls with the floor sloping 6 inches toward center of channel. The wall thickness is 8 inches with double reinforcements and the floor thickness 4 inches between beam construction on which it is placed. Reinforced concrete floor beams and struts are spaced 11-foot centers. The total length was about

14,000 lineal feet and excavation ran 8 cubic yards per lineal foot. The total costs per lineal foot, including all materials and excavation, was $23. Figs. 29 and 30, page 135, show views of the structure.

Small Concrete Channels. An example of this is the Verdugo Conduit, constructed in 1927, of which 2500 lineal feet was built. It has a grade ranging from 2.09 per cent to 1.88 per cent and consists of an open box 43 feet wide and 8-foot walls. The floor drops 12 inches from either wall to the center of the channel. The walls are 9 inches thick with double reinforcement. The floor varies from 6 inches to 9 inches in thickness. Its capacity with a 2-foot freeboard, is 11,700 second-feet. The cost per lineal foot was $25. Fig. 31, page 136, shows the structure.

Another example of a smaller structure is the Rubio Conduit, built in the fall of 1927 with a total length of 1200 feet. Its grade varies from 1.25 per cent to 1.75 per cent and it consists of a rectangular concrete open conduit 26 feet in width with side walls 6 feet in height. With 12-inch freeboard, it has a capacity of 4300 second-feet. Its cost, including excavation, was $20 per lineal foot. Fig. 32, page 136, shows its construction.

Rubble Walls. In suitable localities this type of structure is of value, although care must be taken either to place it on suitable foundations or to construct cross walls to prevent undercutting or cutting away of streambed.

An example of this is the recently completed Sierra Madre Channel, where the water is desilted by means of a debris dam. It was placed on a canyon where the grade was 5.2 per cent and consisted of 2 rubble walls 6 feet in height and 24 feet apart. Walls were built 6 feet above ground surface and 3 feet or more below, of a gravity section having an 18-inch top width and a 1 to 4 slope to the ground surface. Boulders from the streambed were used with cement and lime mortar. The cost, not including streambed excavation, was $8 per cubic yard of masonry. Figs. 33 and 34, page 137, show its construction.

Gunite or Concrete Facing. The district has under consideration a reinforced concrete facing, the lower portion of which consists of flexible weighted blocks. In thickness it will vary from 2½ to 3½ inches. Experiments are now being conducted to determine its suitability. Its cost is 15 cents to 20 cents per square foot. Fig. 35, page 138, shows a section of this work.

Clearing Operation. Clearing varies greatly with the type of work. A recent section of the upper Los Angeles River, whose clearing involved taking out heavy brush and trees up to 4 feet in diameter, cost $1,200 per mile, for hand work. The channel had a top width of 100 feet and a depth of 20 feet and a view of its condition after clearing is shown in Fig. 36, page 138.

FIG. 7—Check Dams in Pickens Canyon. Third and fourth above footbridge near White place.

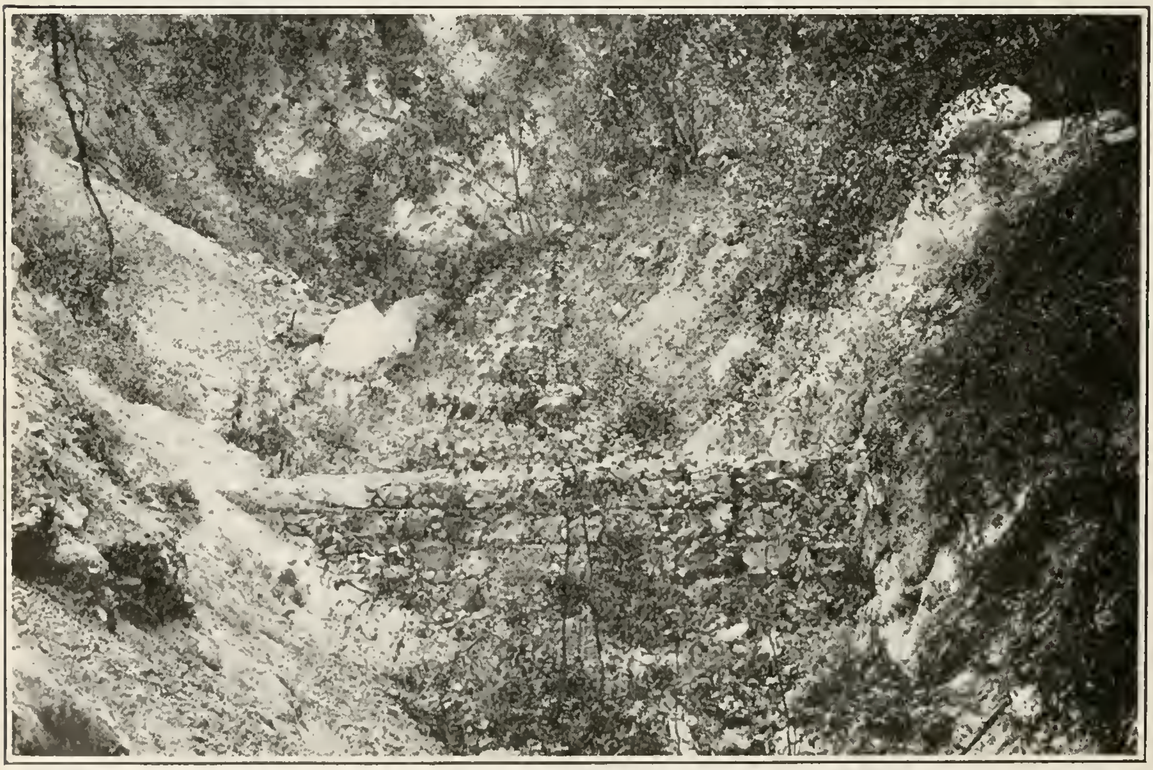

FIG. 8—Check Dams in Pickens Canyon. First and second above footbridge near White place.

FIG. 9—Channel Control. Single pipe and wire mesh, Junction San Dimas and Big Dalton Wash.

FIG. 10—Channel Control. Rock wall mattress construction on San Gabriel River south of Foothill Boulevard.

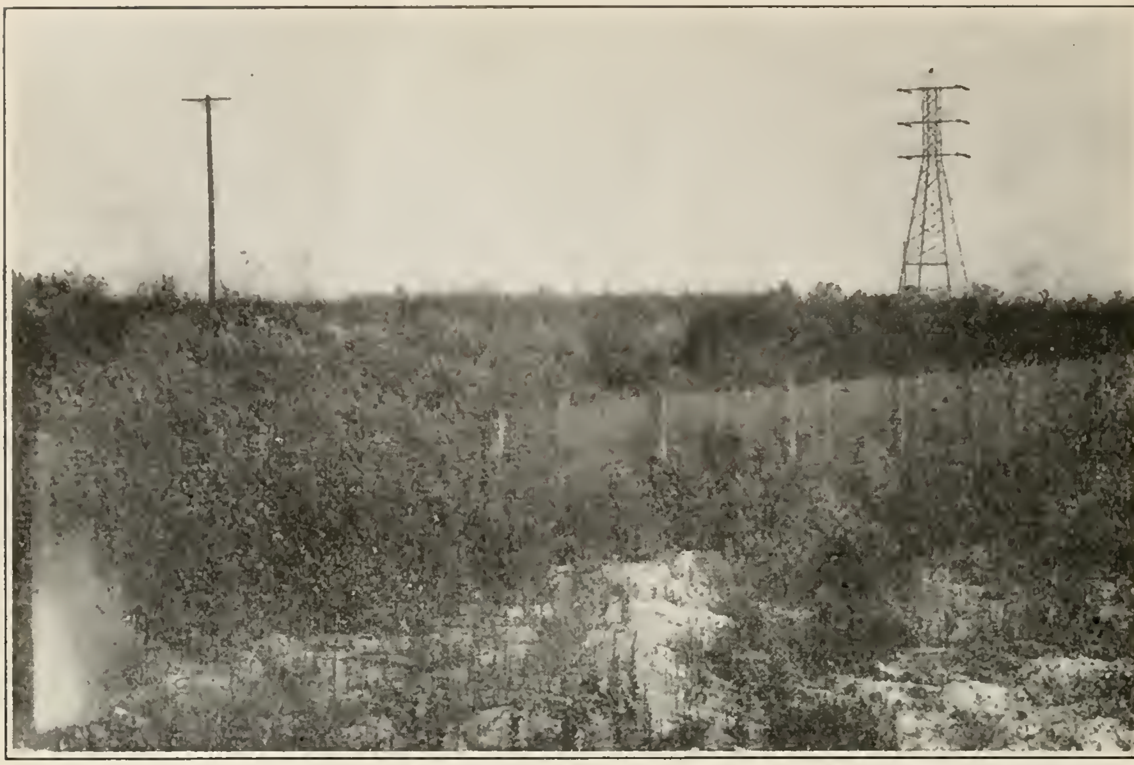

FIG. 11—Channel Control. Piling and wire mesh, east bank of Los Angeles River, below Pacific Electric Railway Bridge near Whittier.

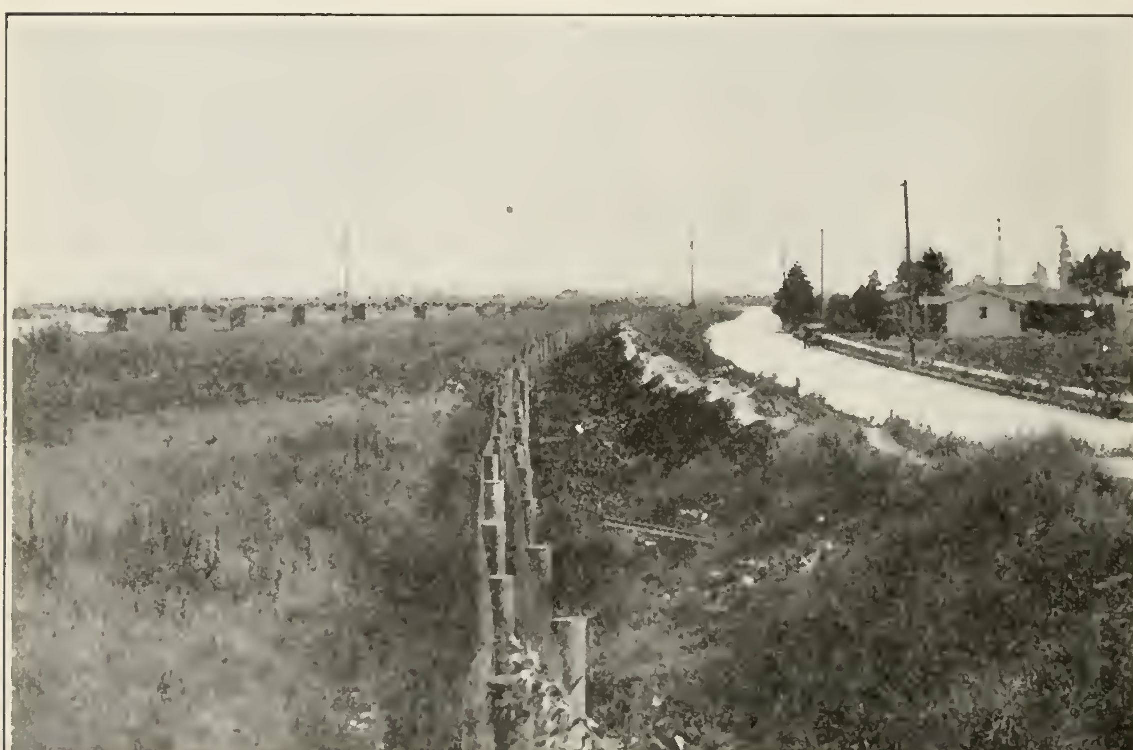

FIG. 12—Channel Control. Piling and wire mesh, west bank of Los Angeles River, below Pacific Electric Railway Bridge near Whittier.

FIG. 13—Channel Control. Rock wall mattress overturned on San Gabriel River north of Foothill Boulevard.

FIG. 14—Channel Control. Rock wall mattress overturned on San Gabriel River north of Foothill Boulevard.

FIG. 15—Channel Control. Same overturned rock wall mattress shown in Fig. 13, still effective in bank protection.

FIG. 16—Channel Control. Same overturned rock wall mattress shown in Fig. 13, still effective in bank protection.

FIG. 17—Channel Control. Long Beach Channel north of Anaheim Bridge.

FIG. 18—Channel Control. Long Beach Channel north of Anaheim Bridge, showing riprap.

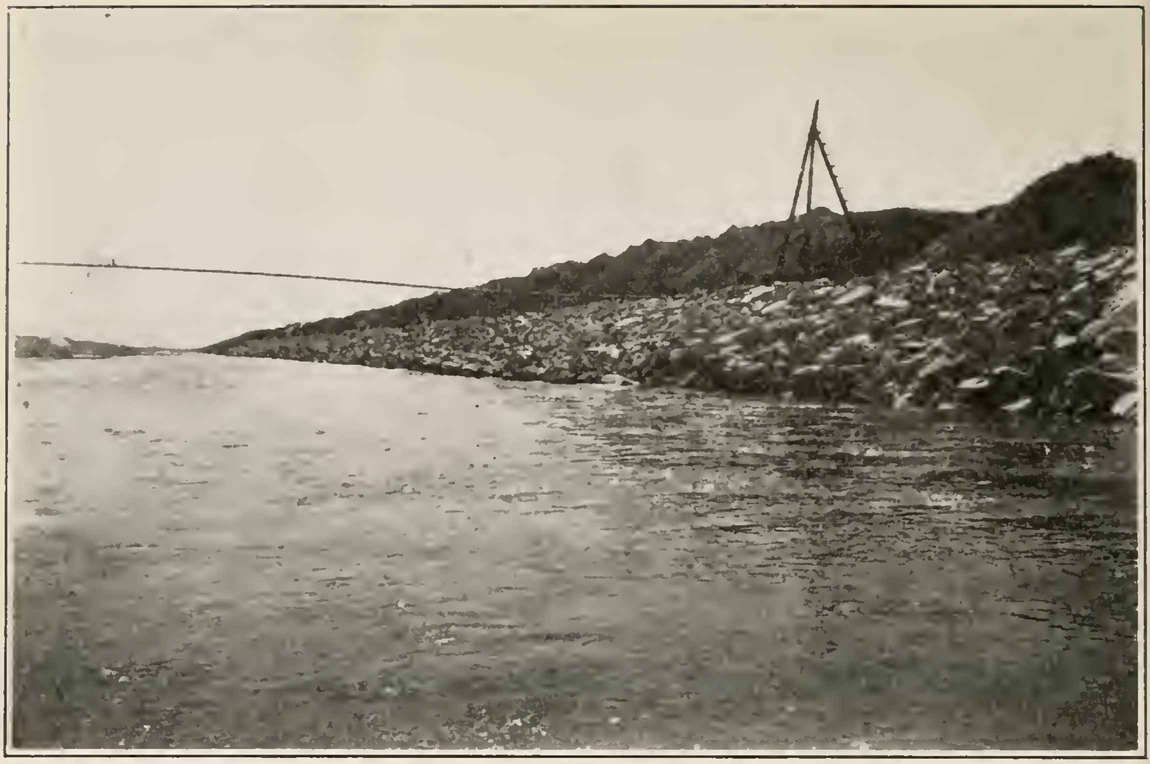

FIG. 19—Channel Control. Los Angeles River south from Workman Station.

FIG. 20—Channel Control. Junction of Los Angeles River and Rio Hondo at Workman Station.

FIG. 21—Rock and wire mattress. Placing rock preparatory to sewing.

FIG. 22—Rock and wire mattress. Sewing mat with tie wires.

FIG. 23—Los Angeles River near Universal City. Four-inch rock and wire mattress.

FIG. 24—Double line, pipe and wire.

FIG. 25—Single line, piling and wire.

FIG. 26—Double line, piling and wire.

FIG. 27—Typical check dam construction.

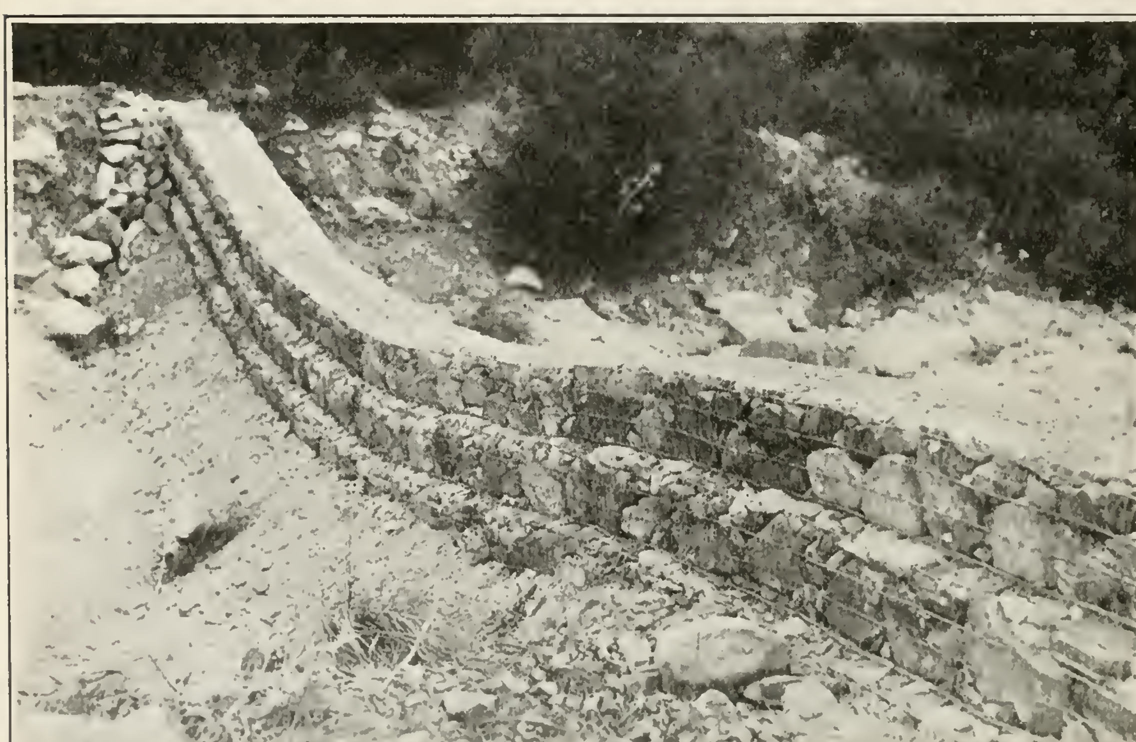

FIG. 28—Typical check dam construction.

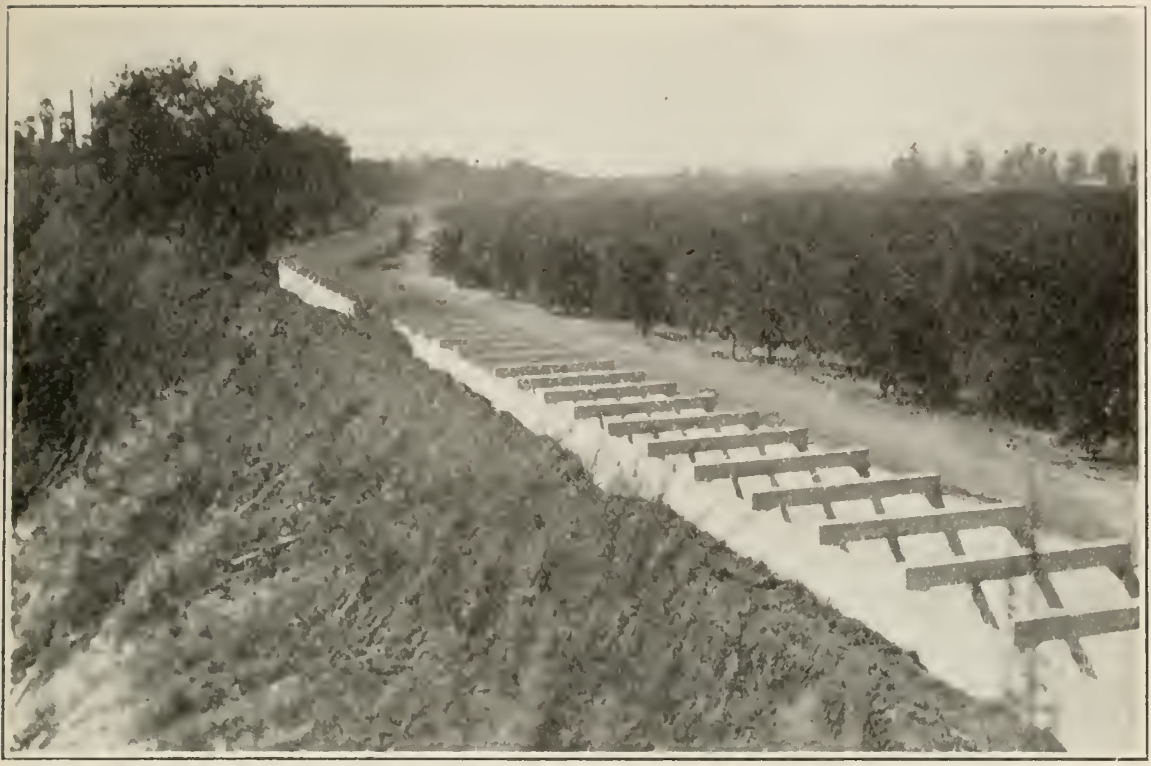

Fig. 29—Puddingstone Conduit.

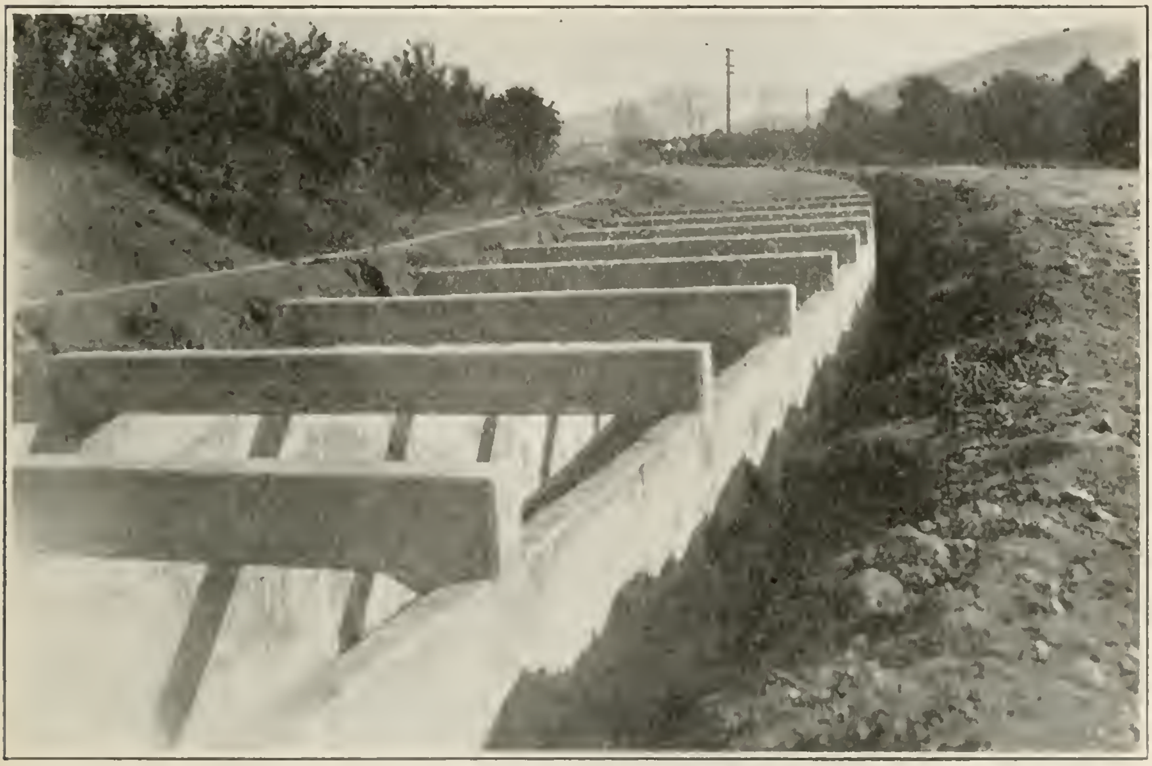

Fig. 30—Puddingstone Conduit.

FIG. 31—Verdugo Conduit.

FIG. 32—Rubio Conduit.

FIG. 33—Sierra Madre Conduit—rubble wall construction.

FIG. 34—Sierra Madre Conduit—rubble wall construction.

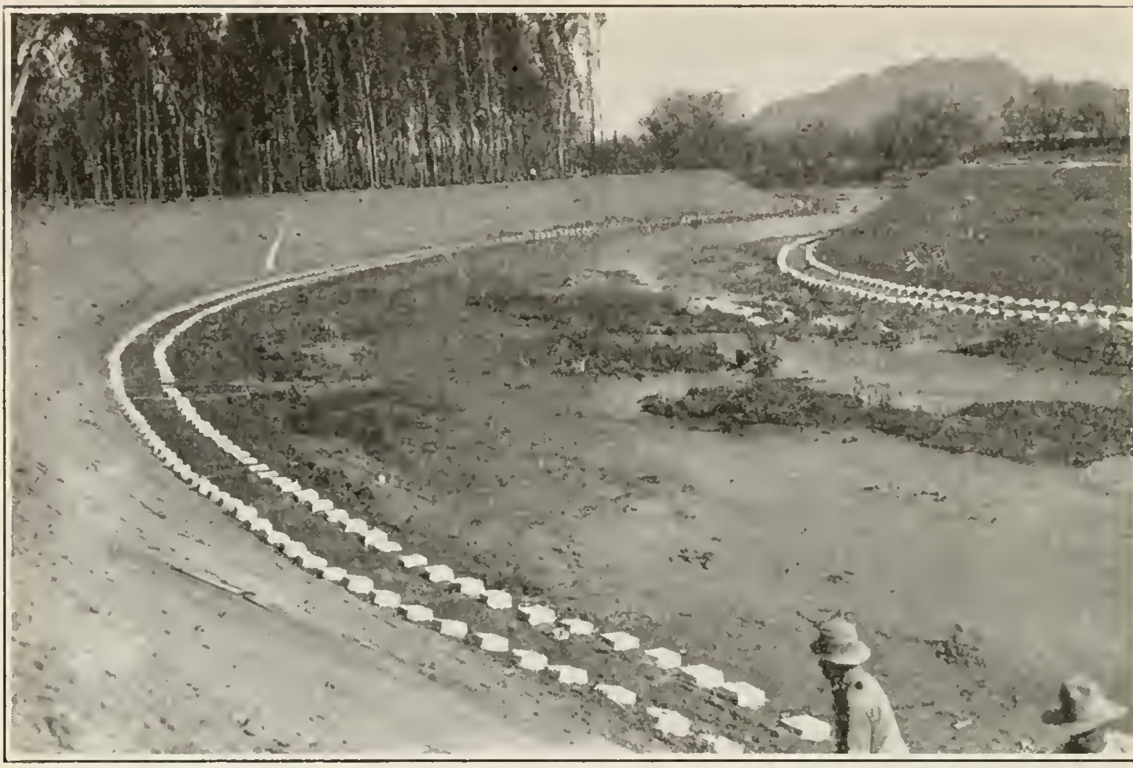

FIG. 35—Los Angeles River. Gunite construction, looking downstream from Pacoima Avenue.

FIG. 36—Los Angeles River. Channel clearing.

OPERATION OF RESERVOIRS FOR FLOOD CONTROL*

Weather Maps. The first essential in flood control operation of reservoirs is accurate weather maps covering thoroughly all of the areas from which storms may be expected. By this means the appearance of any storm can be noted, and steps taken to be in readiness for it in case it should strike this district. The present maps cover an area up to about 2000 miles to sea to the west and toward the Hawaiian Islands, but do not cover the areas to the south and southwest, leaving a blank space on the map, that will have to be filled in to make the weather map 100 per cent efficient.

Character of Storms. For flood control purposes we have classified storms into two classes, minor and major storms. Minor storms are all storms that approach this district from the north or west. Major storms are all storms that approach this district from the south and southwest.

The above classification will hold for the first storm of the season. For additional storms a decision will have to be made, based on judgment as to whether a sufficient saturation of the watersheds exists that will convert a minor storm into a major storm, by increasing the percentage of precipitation that will run off. The same conditions would convert a major storm into what would be classified as an exceptional storm having a record-breaking run-off.

Operation Studies. Studies are made of the operation of all reservoirs in which hydrographs of stream flow are available for one or two-hour periods, assuming the reservoir filled to various points by previous run-off, and assuming various gate openings. By this means we can know definitely what regulation would have been provided under certain definite conditions in the past, if the dam had been built previous to the occurrence of the storm being considered.

Valve or Gate Opening. From the operation studies a size of gate opening can be determined that will give the maximum amount of regulation during minor and major storms. At the beginning of the flood season the valves or gates are opened to an amount that will give regulation in minor storms, and are left in that position until the weather map shows the possibility of a major storm approaching, when the discharge outlets are opened in advance to the proper opening required. For exceptional storms discharge openings should be opened to the maximum amount as this is the special case for which their size was determined in the original design.

The important thing to bear in mind is that we must not sacrifice our regulation in minor storms by having too large an outlet opening on the chance that a major storm might occur.

It is not necessary to constantly change valve or gate opening during a storm as the operation studies show that a constant outlet opening gives a better regulation than a constant discharge.

*Contributed by E. C. Eaton, Chief Engineer, Los Angeles County Flood Control District.

Caretakers. Caretakers must be provided on all important dams, supplemented by engineers during flood periods. It is not felt that we have the right to store water in a reservoir unless it is under observation, especially, if the reservoir is between three-quarters full to full. In this latter case it is believed that the dam should be under constant supervision night and day and that the necessary light should be installed to facilitate the night inspections.

General. A complete system of standard and automatic rain gages should be established in all drainage areas connected by substantial telephone lines to the main office so that prompt advice can be given of the onset of any heavy precipitation.

The commencement of all storms should be watched for information as to the type of storm. Serious storms being indicated by heavy precipitations at certain points, by a decided increase of the mountain over the valley rainfall, and by the onset of heavy rain squalls. It has been noted that at certain places in the mountains located in what are characterized as heavy precipitation zones, the rainfall will have high intensity earlier than elsewhere, thus giving advance notice to the rest of the district.

Stream gaging stations should be established above and below all reservoirs to give the unregulated and regulated flow. The stations below give a graphic record of the amount of the water released, which is of great advantage when statements and claims are made that damage has been caused by the released water.

Size of Reservoir. As the size of the reservoir is increased in relation to the drainage area, the flood control operation becomes easier on account of the greater available storage to take care of emergencies.

Telephone Lines. On account of the use of telephone lines for obtaining information, it is essential that they be constructed in such a manner as to remain in operation during a storm. Most of the trouble occurs on the lines in the valley maintained by the telephone companies, but this can be taken care of by a messenger service.

SANTA ANA RIVER BANK PROTECTION WORK*

The Division of Highways recently completed the construction of 2000 lineal feet of protection work along the east bank of the Santa Ana River, at the state highway Chapman avenue bridge in Orange County.

* * * * * * *

Posts, which were spaced 6 feet on centers both longitudinally and transversely, consisted of 3½-inch O. D. tubing galvanized. The posts were approximately 20 feet long and were driven into the ground 13 or more feet and projected above the ground surface 6 feet. Diagonal braces made of the same size tubing were placed on the front line or river side in each panel, and were used on each alternate panel transversely from the front line of posts to the back line of posts, affording rigid construction. Galvanized ⅝-inch bolts were used to fasten the braces in place.

Along the row of posts on the river side there was placed 8 feet of Ellwood type "I" fencing, which was composed of two 58-inch widths of the fencing which were lapped 20 inches at the ground line, where the wear is the greatest. The upper width of fencing came to within 18 inches below the ground surface, while the lower width of fencing extended 42 inches below the ground surface.

One 58-inch width of Ellwood type "I" fencing was fastened along the back row of posts and extended 10 inches below the ground surface, with 4 feet above the surface. This type of fencing has a 2-inch mesh and is woven with two-strand No. 12½ cables and No. 14 cross wires. The fencing was stretched tight and securely fastened to the pipe posts with tie wire.

When all fence wire was in place, the 6-foot space between the two parallel lines of fence was filled with brush, walnut tree limbs and rock to weight it down.

* * * * * * *

The cost of constructing the bank protection work per lineal foot is as follows:

Labor (equipment, supplies, etc.)	
Setting posts and braces	$0.546
Stretching fence fabric	0.099
Cutting brush, hauling and placing	0.412
Excavate to let fabric into ground and remove trash and old concrete encountered	0.328
Materials	
3½-inch O. D. galv. posts and braces on job	2.124
Fence fabric, delivered to job	0.353
Tie wire	0.004
Bolts	0.037
Total cost per lineal foot	$3.903

The average cost of driving the 712 posts 13 or more feet into the ground was $1.44 each, while the average cost of fitting and bolting the braces in place was 22 cents each.

*Reprinted from "California Highways and Public Works"—1928.

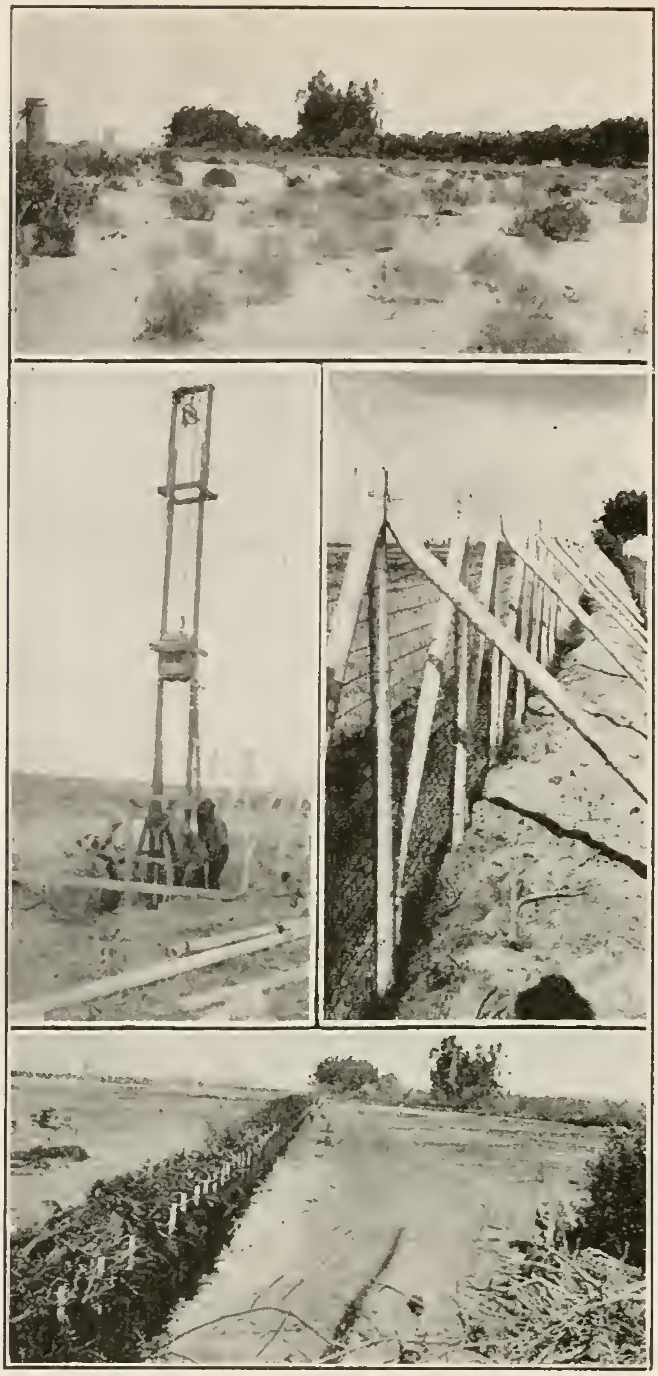

FIG. 36a—Top view shows bank destruction; center views, pile driver and fence; bottom view, completed revetment.

PROTECTION WALLS BUILT IN SAN BERNARDINO COUNTY

A type of protection wall built by the county of San Bernardino has the following dimensions: 6-foot base, 6-foot height, 2-foot crown, back face vertical and front face ⅔ to 1. The method of construction consists of laying down galvanized wire mesh on the subgrade, transversely to the wall. The ends are wrapped over the completed wall and tied, forming a mass completely surrounded by wire netting. Sets of four tie wires are carried through the interior of the mass, at three foot intervals. The wall is composed of boulders, such as can be handled by hand.

An important addition is the placing of wing walls attached to the base at 75-foot intervals. These wing walls are about 3 feet in diameter, and 15 feet long, and are placed at an angle of 30 degrees to the wall. This wing wall is also wound with mesh wire. These serve to prevent scour along the base of the wall.

The cost depending on the accessibility of rock, varies from $1.50 to $3 per lineal foot of wall. Examples of such construction are along San Antonio wash, near Claremont, below Foothill Boulevard.

CHAPTER 3

SURFACE AND UNDERGROUND RESERVOIRS

Major Existing Surface Reservoirs. The following Table 16 covers the major existing reservoirs. Numerous smaller reservoirs and tanks are in use in connection with municipalities and irrigation distribution.

TABLE 16. MAJOR EXISTING RESERVOIRS IN WATERSHED OF THE SANTA ANA RIVER

	Stream	Capacity, acre-feet
Bear Valley	Santa Ana	70,100
Yucaipa	Potato	500
El Casco	San Timoteo	110
Mockingbird	Gage Canal	640
Lee Lake	Temescal	800
Yorba	Anaheim Canal	1,180
Tuffree	Anaheim Canal	80
Alvord	Riverside Canal	300
Total		73,710

TABLE 17. UNDERGROUND RESERVOIRS

The estimated capacity of underground reservoirs under certain assumptions has been determined by hydraulic considerations under section 8, page 202. The general estimated results for each basin are shown as follows:

Basin	Estimated maximum capacity reached between 1913 and 1928, acre-feet
Upper (exclusive of Yucaipa and Beaumont valleys)	514,400
Jurupa	114,200
Cucamonga	345,200
Temescal	126,000
Lower	349,700
Total	1,449,500

Surface Reservoir Sites Investigated. The Santa Ana investigation of 1926-27 made surveys of numerous reservoir sites, which appeared to exist topographically. These reservoir surveys are shown on Map 13, sheets 1 and 2, in pocket. The capacities and cost of each were estimated for varying heights of dam. Typical calculations are published in the following pages. The fact of survey and calculation carries with it no inference as to anticipated feasibility. The reconnaissance was made for information. In certain cases the lack of feasibility may be demonstrated by these surveys and calculations. No other factors of feasibility, such as water supply, are stated with these figures. They represent only a digest of accumulated data on reservoirs which are published for public use.

Unit prices used in making these estimates are as follows:

Cement	$3.08 per bbl.
Sand	0.06 to 0.69 per cu. yd.
Gravel	1.28 to 1.37 per cu. yd.
Lumber	27.00 per M. B. M.
Trash Racks	5.00 per cwt.
Sheet Piling	2.85 per cwt.
Spillway Gates	10.00 per cwt.
Butt Strap Pipe	5.50 per cwt.
Reinf. Steel	2.45 per cwt.
Needle Valves	25.00 per cwt.
Haul was figured at	0.25 per ton mile

The above prices are base prices and do not include freight, storage, handling or haul, which are calculated for each individual reservoir site.

The cost of mass concrete in place, exclusive of material, was derived as follows:

Forms	$ .35 per cubic yard
Mixing and placing	1.50 per cubic yard
Water	.07 per cubic yard
Finishing	.05 per cubic yard
Plant charge	.85 per cubic yard
Total	$2.82 per cubic yard

Similar costs, including steel cost, but exclusive of other material costs, for reinforced concrete in spillways, piers, parapets and bridges varied from $7 to $17.50 per cubic yard. The base price for concrete in place, including all costs, was:

For mass concrete	$6.85 per cubic yard
For reinforced concrete	$11.65 to $23 per cubic yard

The type of structure and cross-section used in estimates are shown in Plate 2, page 146.

The cost of lands was taken at three to five times the assessed valuation.

The estimates for Upper and Lower Prado reservoir sites are taken from estimates of the chief engineer, Orange County Flood Control District and are on somewhat different basis than the foregoing.

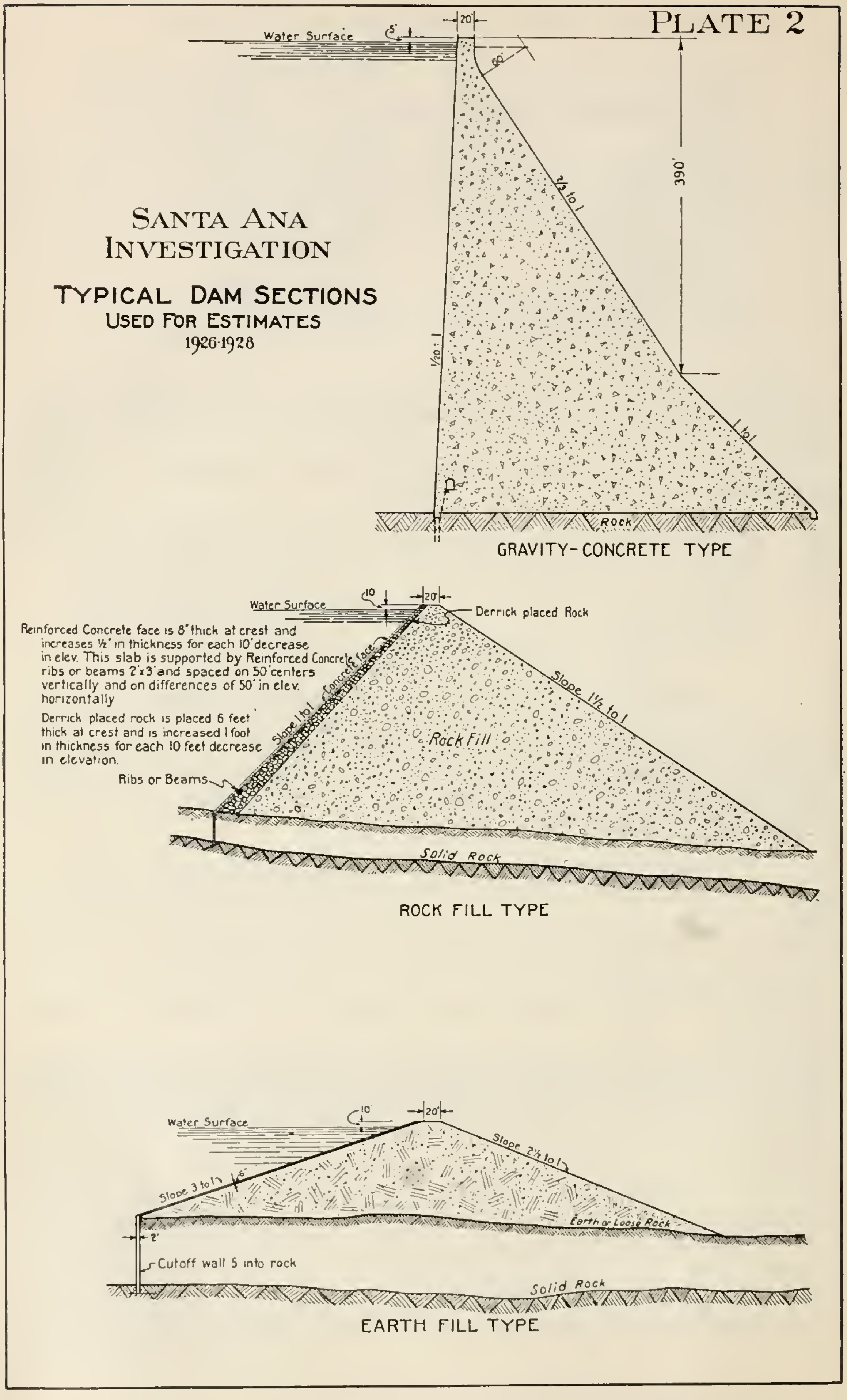
PLATE 2
SANTA ANA INVESTIGATION
TYPICAL DAM SECTIONS USED FOR ESTIMATES
1926-1928
Water Surface
5'
20'
390'
2/3 to 1
1/20 : 1
1 to 1
Rock
GRAVITY-CONCRETE TYPE
Water Surface
10'
20'
Derrick placed Rock
Reinforced Concrete face is 8" thick at crest and increases 1/2" in thickness for each 10' decrease in elev. This slab is supported by Reinforced Concrete ribs or beams 2'x3' and spaced on 50' centers vertically and on differences of 50' in elev. horizontally
Derrick placed rock is placed 6 feet thick at crest and is increased 1 foot in thickness for each 10 feet decrease in elevation.
Concrete face
Slope 1 to 1
Slope 1½ to 1
Rock Fill
Ribs or Beams
Solid Rock
ROCK FILL TYPE
Water Surface
10'
20'
Slope 3 to 1
Slope 2½ to 1
Earth or Loose Rock
2'
Cutoff wall 5 into rock
Solid Rock
EARTH FILL TYPE

ONTARIO RESERVOIR ON SAN ANTONIO CREEK

See Map 13, Sheet 1

Elevation, stream bed	2,655 feet	Capacity, reservoir	9,260 acre-feet
Elevation, crest	2,905 feet	Capacity, spillway	5,800 second-feet
Elevation, flowline	2,900 feet	Capacity, flood outlets	700 second-feet
Depth of water	245 feet	Area of reservoir	95 acres
Total cost	$5,280,800	Cost per acre-foot of storage	$570
Type of dam	concrete gravity	Upstream slope	1/20 : 1
Width of crest	20 feet	Downstream slope	2/3 : 1
Type of spillway	overflow	Depth of water in spillway	6 feet
Spillway equipment	2 60-foot drum gates	Length of spillway	120 feet
Concrete, cubic yards	470,270		

COST ESTIMATE

Exploration	$10,000	
Diversion during construction	5,000	
Clearing reservoir	5,000	
Dam and spillway	3,655,300	
Lands and improvements	185,200	
Flood control features	included with dam	
Miscellaneous	125,000	
Cost, without overhead		$3,985,500
Administration, engineering and contingencies		996,400
Interest during construction		298,900
Total cost		$5,280,800

NARROWS RESERVOIR ON CUCAMONGA CREEK

See Map 13, Sheet 1

Elevation, stream bed	2,585 feet	Capacity, reservoir	3,530 acre-feet
Elevation, crest	2,855 feet	Capacity, spillway	2,360 second-feet
Elevation, flowline	2,845 feet	Capacity, flood outlets	300 second-feet
Depth of water	260 feet	Area of reservoir	40 acres
Total cost	$3,022,900	Cost per acre-foot of storage	$856
Type of dam	rock fill	Upstream slope	1 : 1
Width of crest	20 feet	Downstream slope	1½ : 1
Type of spillway	channel	Depth of water in spillway	6 feet
Spillway equipment	1 52-foot drum gate	Length of spillway	52 feet
Rock, cubic yards	880,640		

COST ESTIMATE

Exploration	$10,000	
Diversion during construction	5,000	
Clearing reservoir	2,000	
Dam and spillway	2,102,400	
Lands and improvements	2,000	
Flood control features	included with dam	
Miscellaneous	160,000	
Cost, without overhead		$2,281,400
Administration, engineering and contingencies		570,400
Interest during construction		171,100
Total cost		$3,022,900

TURK BASIN RESERVOIR ON LYTLE CREEK

See Map 13, Sheet 1

Elevation, stream bed	2,355 feet	Capacity, reservoir	22,665 acre-feet
Elevation, crest	2,623 feet	Capacity, spillway	10,800 second-feet
Elevation, flowline	2,613 feet	Capacity, flood outlets	1,620 second-feet
Depth of water	258 feet	Area of reservoir	280 acres
Total cost	$7,703,700	Cost per acre-foot of storage	$340
Type of dam	rock fill	Upstream slope	1 : 1
Width of crest	20 feet	Downstream slope	1½ : 1
Type of spillway	channel	Depth of water in spillway	15 feet
Spillway equipment	1 60-foot drum gate	Length of spillway	60 feet
Rock, cubic yards	2,013,740		

COST ESTIMATE

Exploration	$20,000	
Diversion during construction	20,000	
Clearing reservoir	14,000	
Dam and spillway	5,363,300	
Lands and improvements	100,500	
Flood control features	included with dam	
Miscellaneous	127,000	
Cost without overhead		$5,644,800
Administration, engineering and contingencies		1,411,200
Interest during construction		617,700
Total cost		$7,703,700

KEENBROOK RESERVOIR ON CAJON CREEK

See Map 13, Sheet 1

Elevation, stream bed	2,585 feet	Capacity, reservoir	16,570 acre-feet
Elevation, crest	2,765 feet	Capacity, spillway	9,240 second-feet
Elevation, flowline	2,755 feet	Capacity, flood outlets	1,390 second-feet
Depth of water	170 feet	Area of reservoir	295 acres
Total cost	$5,390,600	Cost per acre-foot of storage	$325
Type of dam	rock fill	Upstream slope	1 : 1
Width of crest	20 feet	Downstream slope	1½ : 1
Type of spillway	channel	Depth of water in spillway	15 feet
Spillway equipment	1 52-foot drum gate	Length of spillway	52 feet
Rock, cubic yards	451,590		

COST ESTIMATE

Exploration	$10,000	
Diversion during construction	5,000	
Clearing reservoir	15,000	
Dam and spillway	1,393,400	
Lands and improvements	2,581,000	
Flood control features	included with dam	
Miscellaneous	64,000	
Cost, without overhead		$4,068,400
Administration, engineering and contingencies		1,017,100
Interest during construction		305,100
Total cost		$5,390,600

HIGHLAND RESERVOIR ON CITY CREEK

See Map 13, Sheet 1

Elevation, stream bed	1,970 feet	Capacity, reservoir	5,970 acre-feet
Elevation, crest	2,270 feet	Capacity, spillway	3,110 second-feet
Elevation, flowline	2,260 feet	Capacity, flood outlets	310 second-feet
Depth of water	290 feet	Area of reservoir	75 acres
Total cost	$3,138,000	Cost per acre-foot of storage	$526
Type of dam	rock fill	Upstream slope	1 : 1
Width of crest	20 feet	Downstream slope	1½ : 1
Type of spillway	channel	Depth of water in spillway	8 feet
Spillway equipment	1 45-foot drum gate	Length of spillway	45 feet
Rock, cubic yards	897,270		

COST ESTIMATE

Exploration	$10,000	
Diversion during construction	5,000	
Clearing reservoir	4,000	
Dam and spillway	2,193,400	
Lands and improvements	55,900	
Flood control features	included with dam	
Miscellaneous	100,000	
Cost, without overhead		$2,368,300
Administration, engineering and contingencies		292,100
Interest during construction		177,600
Total cost		$3,138,000

FILIREA FLATS RESERVOIR ON SANTA ANA RIVER

See Map 13, Sheet 1

Elevation, stream bed	4,215 feet	Capacity, reservoir	4,600 acre-feet
Elevation, crest	4,405 feet	Capacity, spillway	10,800 second-feet
Elevation, flowline	4,400 feet	Capacity, flood outlets	------ second-feet
Depth of water	185 feet	Area of reservoir	76 acres
Total cost	$2,044,600	Cost per acre-foot of storage	$445
Type of dam	concrete gravity	Upstream slope	1/20 : 1
Width of crest	20 feet	Downstream slope	2/3 : 1
Type of spillway	overflow	Depth of water in spillway	15 feet
Spillway equipment	1 54-foot drum gate	Length of spillway	54 feet
Concrete, cubic yards, 121,080 in main dam; 29,120 cubic yards in auxiliary dam.			

COST ESTIMATE

Exploration	$10,000	
Diversion during construction	5,000	
Clearing reservoir	-------	
Dam and spillway	1,466,000	
Lands and improvements	400	
Flood control features	-------	
Miscellaneous	61,700	
Cost, without overhead		$1,543,100
Administration, engineering and contingencies		385,800
Interest during construction		115,700
Total cost		$2,044,600

HEMLOCK RESERVOIR ON SANTA ANA RIVER

See Map 13, Sheet 1

Elevation, stream bed	2,545 feet	Capacity, reservoir	12,175 acre-feet
Elevation, crest	2,805 feet	Capacity, spillway	second-feet
Elevation, flowline	2,800 feet	Capacity, flood outlets	second-feet
Depth of water	255 feet	Area of reservoir	147 acres
Total cost	------	Cost per acre-foot of storage	------
Type of dam	concrete gravity	Upstream slope	------
Width of crest	------	Downstream slope	------
Type of spillway	------	Depth of water in spillway	------
Spillway equipment	------	Length of spillway	------
Concrete, cubic yards	433,500		

COST ESTIMATE

Cost estimate not figured.

Quantity estimate shows 35.6 cubic yards per acre-foot of storage.

Probable cost by comparison with Forks Dam 315 feet high, is $5,125,000 which gives $421 per acre-foot storage.

FORKS RESERVOIR ON SANTA ANA RIVER

See Map 13, Sheet 1

Elevation, stream bed	3,300 feet	Capacity, reservoir	19,625 acre-feet
Elevation, crest	3,615 feet	Capacity, spillway	25,600 second-feet
Elevation, flowline	3,610 feet	Capacity, flood outlets	8,280 second-feet
Depth of water	310 feet	Area of reservoir	------ acres
Total cost	$7,996,700	Cost per acre-foot of storage	$407
Type of dam	concrete gravity	Upstream slope	1/20 : 1
Width of crest	20 feet	Downstream slope	2/3 : 1
Type of spillway	overflow	Depth of water in spillway	8 feet
Spillway equipment	6 54-foot drum gates	Length of spillway	327 feet
Concrete, cubic yards	677,230		

COST ESTIMATE

Exploration	$20,000	
Diversion during construction	20,000	
Clearing reservoir	11,000	
Dam and spillway	5,452,200	
Lands and improvements	10,000	
Flood control features	298,400	
Miscellaneous	95,000	
Cost without overhead		$5,906,600
Administration, engineering and contingencies		1,475,800
Interest during construction		617,600
Total cost		$8,000,000

MENTONE RESERVOIR ON SANTA ANA RIVER

See Map 13, Sheet 1

Elevation, stream bed	1,960 feet	Capacity, reservoir	20,200 acre-feet
Elevation, crest	2,205 feet	Capacity, spillway	24,600 second-feet
Elevation, flowline	2,195 feet	Capacity, flood outlets	8,100 second feet
Depth of water	235 feet	Area of reservoir	------ acres
Total cost	$8,909,300	Cost per acre-foot of storage	$436
Type of dam	rock fill	Upstream slope	1 : 1
Width of crest	20 feet	Downstream slope	1½ : 1
Type of spillway	channel	Depth of water in spillway	20 feet
Spillway equipment	2 45-foot drum gates	Length of spillway	90 feet
Rock, cubic yards	1,916,200		

COST ESTIMATE

Exploration	$20,000	
Diversion during construction	20,000	
Clearing reservoir	10,200	
Dam and spillway	5,832,400	
Lands and improvements	217,800	
Flood control features	--------	
Miscellaneous	128,000	
Cost, without overhead		$6,228,400
Administration, engineering and contingencies		1,494,800
Interest during construction		675,800
Total cost		$8,399,000
Flood control features including overhead		510,000
Total cost with flood control features		$8,909,300

CRAFTON RESERVOIR ON MILL CREEK

See Map 13, Sheet 1

Elevation, stream bed	3,000 feet	Capacity, reservoir	16,000 acre-feet
Elevation, crest	3,315 feet	Capacity, spillway	10,240 second-feet
Elevation, flowline	3,305 feet	Capacity, flood outlets	1,540 second-feet
Depth of water	305 feet	Area of reservoir	126 acres
Total cost	$9,364,200	Cost per acre-foot of storage	$585
Type of dam	rock fill	Upstream slope	1 : 1
Width of crest	20 feet	Downstream slope	1½ : 1
Type of spillway	overflow	Depth of water in spillway	8 feet
Spillway equipment	3 45-foot drum gates	Length of spillway	135 feet
Rock, cubic yards	2,681,070		

COST ESTIMATE

Exploration	$20,000	
Diversion during construction	20,000	
Clearing reservoir	5,000	
Dam and spillway	6,436,500	
Lands and improvements	248,700	
Flood control features	included with dam	
Miscellaneous	130,000	
Cost, without overhead		$6,860,200
Administration, engineering and contingencies		1,715,100
Interest during construction		788,900
Total cost		$9,364,200

JURUPA RESERVOIR ON SANTA ANA RIVER

See Map 13, Sheet 1

Elevation, stream bed	690 feet	Capacity, reservoir	65,000 acre-feet
Elevation, crest	775 feet	Capacity, spillway	8,000 second-feet
Elevation, spillway	770 feet	Capacity, flood outlets	10,000 second-feet
Depth of water	80 feet	Area of reservoir	2,400 acres
Total cost	$7,321,623	Cost per acre-foot of storage	$113
Type of dam	gravity concrete	Upstream slope	1/20 : 1
Width of crest	20 feet	Downstream slope	2/3 : 1
Type of spillway	overflow	Depth of water in spillway	5 feet
Spillway equipment	none	Length of spillway	215 feet
Concrete, cubic yards	228,715		

COST ESTIMATE

Exploration	$10,000	
Diversion during construction	30,000	
Clearing reservoir	20,000	
Dam and spillway	2,338,079	
Lands and improvements	2,357,600	
Flood control features	5,000	
Miscellaneous	765,000	
Cost, without overhead		$5,525,679
Administration, engineering and contingencies		1,381,419
Interest during construction		414,525
Total cost		$7,321,623

CHINO RESERVOIR ON CHINO CREEK

See Map 13, Sheet 2

Elevation, stream bed	490 feet	Capacity, reservoir	38,800 acre-feet
Elevation, crest	560 feet	Capacity, spillway	3,000 second-feet
Elevation, flowline	550 feet	Capacity, flood outlets	------ second-feet
Depth of water	60 feet	Area of reservoir	------ acres
Total cost	$2,174,000	Cost per acre-foot of storage	$56
Type of dam	earth fill	Upstream slope	4 : 1
Width of crest	20 feet	Downstream slope	5 : 1
Type of spillway	channel	Depth of water in spillway	------
Spillway equipment	------	Length of spillway	------

COST ESTIMATE

Exploration	$5,000	
Diversion during construction	10,000	
Clearing reservoir	--------	
Dam and spillway	700,000	
Lands and improvements	935,000	
Flood control features	--------	
Miscellaneous	60,000	
Cost, without overhead		$1,635,000
Administration, engineering and contingencies		409,000
Interest during construction		130,000
Total cost		$2,174,000

UPPER PRADO RESERVOIR

Capacity 180,000 acre-feet

Maximum height of dam 93 feet

DAM	
1,345,200 cu. yds. sand and gravel hydraulically placed	$384,300
46,000 cu. yds. rolled fill of selected material	19,700
245,700 cu. yds. rolled fill of sand and gravel	70,200
19,500 cu. yds. hard rock riprap facing	70,000
CUT-OFF	
2,500 cu. yds. excavation	1,700
3,640 tons steel sheet piling	259,900
18,190 cu. yds. concrete	207,800
Grouting between rows of sheet piling	100,000
SPILLWAY AND RESERVOIR OUTLETS	
444,500 cu. yds. excavation	275,000
58,870 cu. yds. concrete	896,800
148,900 cu. yds. back fill	45,500
130 tons steel sheet piling	12,000
Outlet gates and trash racks	115,800
Underflow by-pass	34,000
Relocation of county highways	636,700
Relocation of A., T. and S. F. Ry.	455,800
Incidentals, contingencies and administration, 15%	537,800
Subtotal	$4,123,000
Lands and improvements required for reservoir	3,467,900
Total, dam and reservoir	$7,590,900
Lands and improvements required for maintenance of river channel between Upper Prado dam site and the ocean	178,300

LOWER PRADO RESERVOIR

Capacity 180,000 acre-feet

Maximum height of dam 155 feet

DAM	
4,897,000 cu. yds. sand and gravel hydraulically placed	$1,007,700
425,200 cu. yds. rolled fill of selected material	182,200
978,100 cu. yds. rolled fill of sand and gravel	279,500
55,400 cu. yds. hard rock riprap facing	189,800
CUT-OFF	
87,800 cu. yds. excavation	41,700
3,410 tons steel sheet piling	243,700
53,200 cu. yds. concrete	503,400
Grouting between rows of sheet piling	100,000
SPILLWAY AND RESERVOIR OUTLETS	
496,800 cu. yds. excavation	250,200
77,400 cu. yds. concrete	923,100
306,100 cu. yds. back fill	72,900
430 tons steel sheet piling	30,900
Outlet gates and trash racks	87,300
UNDERFLOW BY-PASS	
34,700 cu. yds. excavation	8,000
470 cu. yds. concrete	4,400
33,100 cu. yds. gravel and sand back fill	4,500
4,360 feet concrete pipe—30"	15,400
Valves	1,000
PASSING A. U. WATER CO. AND S. A. V. I. CO. CANALS THROUGH RESERVOIR AND DAM	
84,600 cu. yds. excavation	52,800
55,500 cu. yds. back fill	5,500
13,530 cu. yds. concrete	190,300
2,430 feet steel pipe	28,900
18,770 feet concrete pipe	129,500
250 pipe cradles	500
Pile protection	2,000
Needle valves	27,000
Relocating pump plants	5,000
Relocation of county highway	1,015,000
Relocation of A., T. and S. F. Ry.	3,165,000
Incidentals, contingencies and administration, 15%	1,285,100
Subtotal	$9,852,300
Lands and improvements required for reservoir	1,950,000
Total, dam and reservoir	$11,802,300
Lands and improvements required for maintenance of river channel between Lower Prado dam site and the ocean	93,000

CHAPTER 4

DISPOSAL OF RAINFALL*

Early in the Santa Ana River investigation, it became apparent that the absorption of rainfall on the valley floors was one of the most important sources of water supply and that the amount reaching the ground water would be difficult to determine. In December, 1927, at the request of the State Engineer, a special cooperative † investigation was started, by the Division of Agricultural Engineering, Bureau of Public Roads, U. S. Department of Agriculture, to determine the penetration and storage of rain falling upon the valley floors of the Santa Ana River area in Orange, Riverside and San Bernardino counties. After careful consideration of several methods, it was decided to study the problem mainly from a soil moisture standpoint, by taking soil samples to a depth below the root zone. Rainfall penetration stations were established on predominating soil types and studies made of rainfall, run-off, transpiration, evaporation and depth of penetration. The location of these stations is shown on Plate 3.

Although the field work on the investigations is still in progress, it is necessary at this time for the purpose of completing the hydraulic accounting in the Santa Ana River report to make an estimate of the contribution of the rain falling on the valley floor to the ground water supply. Use has been made of the data obtained during the past winter in the Santa Ana area, and of other corroborating data secured in the San Diego and San Fernando valleys, to make the best possible estimate. However, it should be understood that this is a preliminary report and may be modified by subsequent information.

The disposal of rainfall is as follows:

1. Surface run-off.
2. Transpiration.
3. Evaporation.
4. Deep penetration.

Rainfall penetration on the valley floor below the root zone will be estimated indirectly by assigning values to run-off, transpiration and evaporation losses as deduced from one season's work in the Santa Ana area, and three seasons' investigations in the San Diego and San Fernando valleys. These will be analyzed and deducted from each rainstorm. The remainder will be considered to penetrate below the root zone and eventually reach the ground water. Assumptions are for average soil conditions and no attempt is made to show the effect of soil texture on the depth of penetration. Values for the factors to be applied have been assigned as follows:

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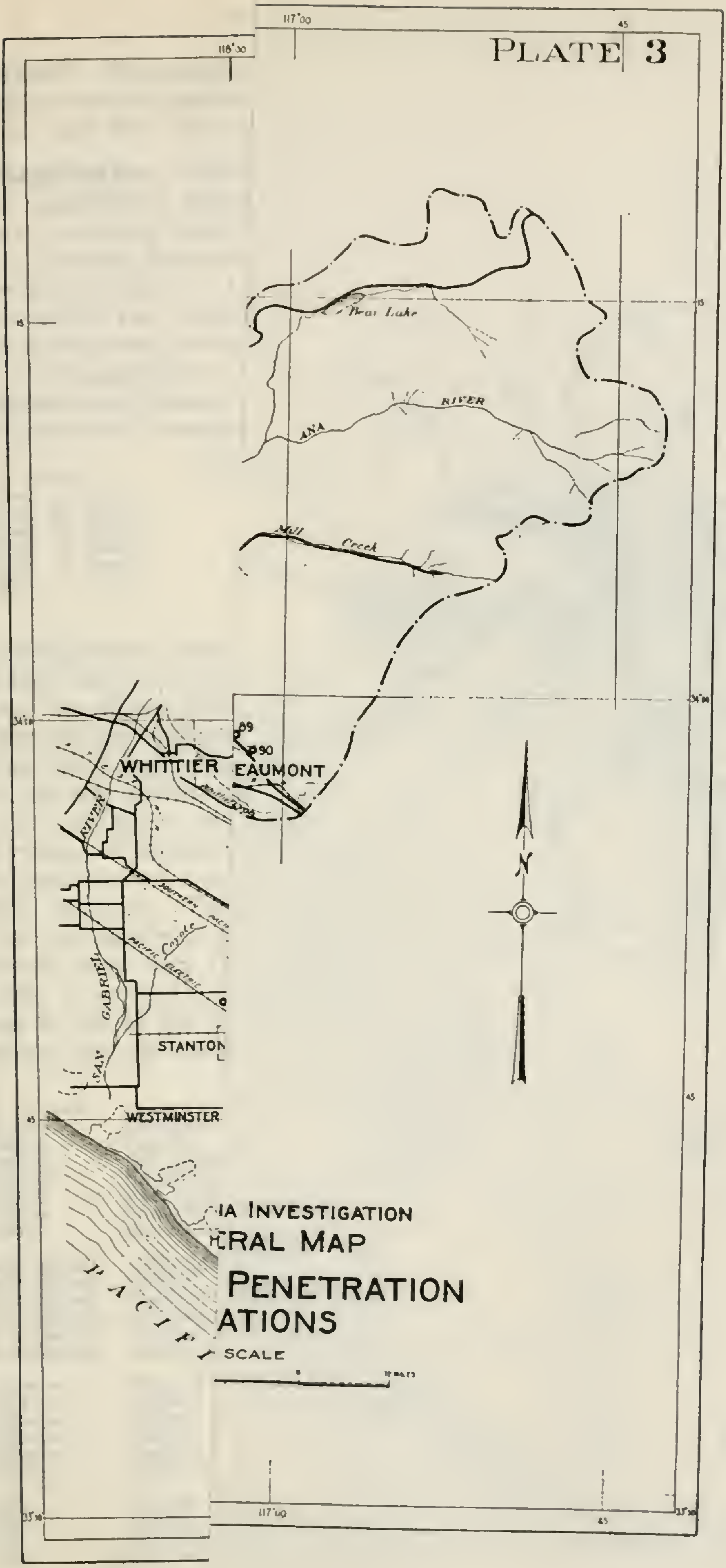
* By Harry F. Blaney, Irrigation Engineer, Division of Agricultural Engineering, Bureau of Public Roads, U. S. Department of Agriculture.

† A cooperative investigation by the Division of Agricultural Engineering of the Bureau of Public Roads of the U. S. Department of Agriculture, the California State Department of Public Works and the Division of Irrigation Investigations and Practice of the University of California; the work is under the general supervision of W. W. McLaughlin, Associate Chief of the Division of Agricultural Engineering, with Harry F. Blaney, Irrigation Engineer, in direct charge of the work assisted by C. A. Taylor, Assistant Irrigation Engineer, and H. W. Kistner.

PLATE 3



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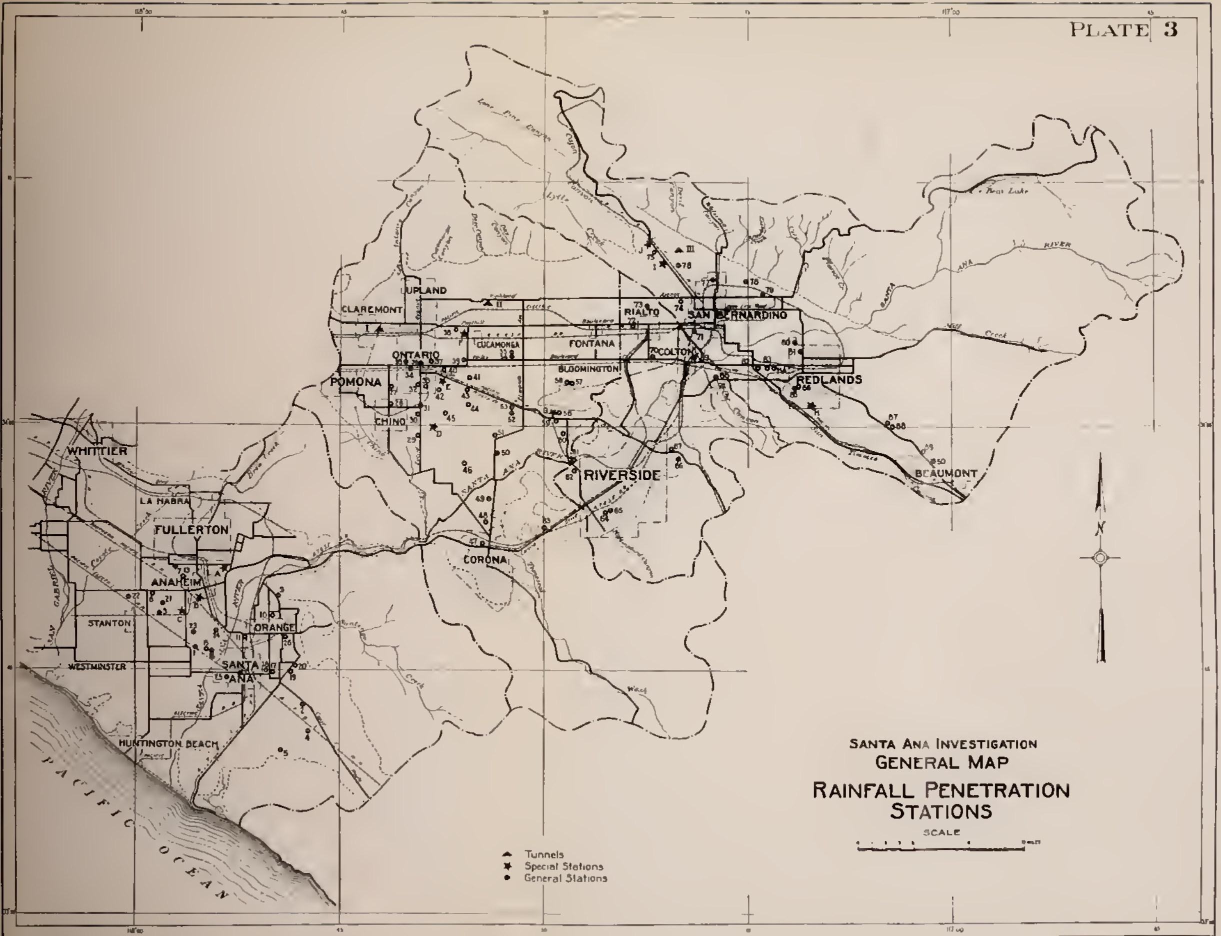
SANTA ANA INVESTIGATION
GENERAL MAP
RAINFALL PENETRATION STATIONS
SCALE
Tunnels
Special Stations
General Stations
UPLAND
CLAREMONT
RIALTO
SAN BERNARDINO
CUCAMONGA
FONTANA
ONTARIO
COLTON
BLOOMINGTON
POMONA
REDLANDS
CHINO
WHITTIER
RIVERSIDE
BEAUMONT
LA HABRA
FULLERTON
CORONA
ANAHEIM
STANTON
ORANGE
WESTMINSTER
SANTA ANA
HUNTINGTON BEACH
PACIFIC OCEAN

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Run-off. Hydrographers of the Santa Ana investigation have determined on certain known areas the run-off rate per square mile. These will be used also on undetermined areas.

Transpiration. After careful consideration of unpublished data from cooperative irrigation investigations in northern San Diego County, covering three seasons, the total average transpiration for all active growing vegetation was taken as 6 acre-inches per acre during the winter period, or 1 acre-inch per month. Transpiration may vary considerably for different crops. Other factors such as temperature, wind movements, humidity, available soil moisture, etc., influence the rate of transpiration.

Intensive soil sampling during the spring of 1927 showed the following rates of transpiration for citrus in northern San Diego County:

Grove	*Estimated per cent maturity*	*Interval*	*Transpiration rate ac. in./ac./30 days*
Lemons, 17 years	100	Mar. 15–May 11	1.33
Lemons, 11 years	75	Mar. 19–May 1	.93
Oranges, 30 years	78	Mar. 15–May 1	1.03
Oranges, 7 years	36	Mar. 15–May 1	.83
Oranges, 7 years	40	Mar. 15–May 1	.90
Oranges, 7 years	42	Mar. 15–May 1	.80
		Average rate	0.97

Investigations have shown that bare lands, vineyards and deciduous orchards that are clean cultivated, have no material transpiration loss during the winter period. Where the water table is within two feet of the surface no transpiration loss will be charged to rainfall as capillary action will supply the necessary moisture needed for plant growth.

In all calculations of rainfall penetration, the deficiency of storage of soil moisture at the end of the summer season must be reckoned in analyzing the following rainy period. There will be no material downward penetration until all of the soil within the root zone has been filled to field capacity. The deficiency of moisture in the soil depends on the initial moisture content of the soil at the beginning of the rainy season and will vary with the kind of crop, depth of root zone, type of soil, amount of irrigation, depth of water table, etc. The following table shows a few of the field determinations made of the deficiency of soil moisture for different crops and conditions:

Type of land	*Location*	*Soil type*	*Crop*	*Deficiency acre inches per acre*
Irrigated	Redlands	Loam	Oranges	3.4
Irrigated	Corona	Sandy loam	Grain	3.0
Irrigated	San Diego County	Sandy loam	Lemons	3.4
Irrigated	San Diego County	Sandy loam	Lemons	2.3
Irrigated	San Diego County	Sandy loam	Lemons	3.5
Irrigated	San Diego County	Sandy loam	Oranges	3.0
Irrigated	San Diego County	Sandy loam	Oranges	2.1
Non-irrigated	Redlands	Loam	Grain	4.2
Non-irrigated	Ontario	Sand	Grass	4.3
Non-irrigated	Cucamonga	Sandy loam	Grass and weeds	5.1
Non-irrigated	Riverside	Clay loam	Grass	5.4
Non-irrigated	Anaheim	Fine sandy loam	Grass and weeds	4.6
Non-irrigated	Anaheim	Fine sandy loam	Grass and weeds	6.1
Deciduous	Ontario	Fine sandy loam	Grapes	6.2
Deciduous	Ontario	Sandy loam	Grapes	8.0
Deciduous	Chino	Silt loam	Walnuts	7.1
Deciduous	Chino	Fine silt loam	Walnuts	7.0
Deciduous	Ontario	Loam	Peaches	7.0
Deciduous	Ontario	Sandy loam	Peaches	7.0
Brush	Muscoy	Sand	Medium brush	7.0
Brush	Muscoy	Sandy loam	Heavy brush	9.9
Brush	San Bernardino	Sandy loam	Light brush	5.6
Brush	Corona	Loam	Light brush	6.0

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Run-off. Hydrographers of the Santa Ana investigation have determined on certain known areas the run-off rate per square mile. These will be used also on undetermined areas.

Transpiration. After careful consideration of unpublished data from cooperative irrigation investigations in northern San Diego County, covering three seasons, the total average transpiration for all active growing vegetation was taken as 6 acre-inches per acre during the winter period, or 1 acre-inch per month. Transpiration may vary considerably for different crops. Other factors such as temperature, wind movements, humidity, available soil moisture, etc., influence the rate of transpiration.

Intensive soil sampling during the spring of 1927 showed the following rates of transpiration for citrus in northern San Diego County:

Grove	*Estimated per cent maturity*	*Interval*	*Transpiration rate ac. in./ac./30 days*
Lemons, 17 years	100	Mar. 15–May 11	1.33
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Oranges, 7 years	36	Mar. 15–May 1	.83
Oranges, 7 years	40	Mar. 15–May 1	.90
Oranges, 7 years	42	Mar. 15–May 1	.80
		Average rate	0.97

Investigations have shown that bare lands, vineyards and deciduous orchards that are clean cultivated, have no material transpiration loss during the winter period. Where the water table is within two feet of the surface no transpiration loss will be charged to rainfall as capillary action will supply the necessary moisture needed for plant growth.

In all calculations of rainfall penetration, the deficiency of storage of soil moisture at the end of the summer season must be reckoned in analyzing the following rainy period. There will be no material downward penetration until all of the soil within the root zone has been filled to field capacity. The deficiency of moisture in the soil depends on the initial moisture content of the soil at the beginning of the rainy season and will vary with the kind of crop, depth of root zone, type of soil, amount of irrigation, depth of water table, etc. The following table shows a few of the field determinations made of the deficiency of soil moisture for different crops and conditions:

Type of land	*Location*	*Soil type*	*Crop*	*Deficiency acre inches per acre*
Irrigated	Redlands	Loam	Oranges	3.4
Irrigated	Corona	Sandy loam	Grain	3.0
Irrigated	San Diego County	Sandy loam	Lemons	3.4
Irrigated	San Diego County	Sandy loam	Lemons	2.3
Irrigated	San Diego County	Sandy loam	Lemons	3.5
Irrigated	San Diego County	Sandy loam	Oranges	3.0
Irrigated	San Diego County	Sandy loam	Oranges	2.1
Non-irrigated	Redlands	Loam	Grain	4.2
Non-irrigated	Ontario	Sand	Grass	4.3
Non-irrigated	Cucamonga	Sandy loam	Grass and weeds	5.1
Non-irrigated	Riverside	Clay loam	Grass	5.4
Non-irrigated	Anaheim	Fine sandy loam	Grass and weeds	4.6
Non-irrigated	Anaheim	Fine sandy loam	Grass and weeds	6.1
Deciduous	Ontario	Fine sandy loam	Grapes	6.2
Deciduous	Ontario	Sandy loam	Grapes	8.0
Deciduous	Chino	Silt loam	Walnuts	7.1
Deciduous	Chino	Fine silt loam	Walnuts	7.0
Deciduous	Ontario	Loam	Peaches	7.0
Deciduous	Ontario	Sandy loam	Peaches	7.0
Brush	Muscoy	Sand	Medium brush	7.0
Brush	Muscoy	Sandy loam	Heavy brush	9.9
Brush	San Bernardino	Sandy loam	Light brush	5.6
Brush	Corona	Loam	Light brush	6.0

After considering the above and many other observations made in southern California during the past two years, the following values are taken for average soil under various conditions:

Type of land	*Deficiency of storage of soil moisture at end of summer season. Acre inches per acre*
Water table 0 feet to 4 feet from surface	0
Water table 4 feet to 6 feet from surface	1
Bare land and dry stream beds	1
Irrigated crops (except deciduous trees and vineyard)	3
Grain, weeds and grass (non-irrigated)	5
Deciduous trees and vineyard	7
Brush	7

Evaporation. There are many factors which affect the evaporation loss after a rainstorm, such as temperature, wind movement, humidity, soil type, kind of vegetation, transpiration, altitude, interception of rain by vegetation, period between storms, etc.

It was found from observations during 1928 that the evaporation loss from a bare soil in the winter months very nearly equals the loss from a free water surface up until the time the soil drains to field capacity. The time required to drain the top soil to field capacity was found to be four days for sandy soils. After draining to field capacity, the surface evaporation loss is readily determined by soil sampling. The average rate of loss after draining to field capacity was found to be .024 inches per day for sandy soils. This information, together with other evidence, indicates that the average evaporation loss from the top soil is about one-half acre-inch per acre after each rainstorm. The interception of rainfall by some types of vegetation may increase the evaporation loss considerably. In moist areas where the water table is near the surface and the soil saturated, no evaporation loss will be considered chargeable to rainfall.

Calculations. In general it is found that every season must be studied separately in order to arrive at the penetration for that season. The same seasonal rainfall may give entirely different penetration, due to varying intensity and distribution of storms. For completing the hydraulic accounting in this report, the seasons 1926-27 and 1927-28 have been computed. In these computations the values given above are used. Known rainfall records as near as possible in total seasonal amount to the required average for an area are used. An example of detail calculations for one station is given, followed by a summary of all detail calculations. A final table is shown for varying rainfall by interpolating between calculated quantities, by graphical method.

Rainfall upon the water surface of the river or moist lands adjacent to the river will be considered as run-off and not a contribution to the ground water. Thus transpiration and evaporation losses will not be charged to rainfall.

TABLE 18. EXAMPLE OF DETAIL CALCULATION OF RAINFALL PENETRATION IN INCHES UPPER BASIN SOUTHEAST PORTION

Irrigated Land

Seasonal rainfall for 1926-27, 20.55 inches. Based on rainfall record of U. S. Weather Bureau at San Bernardino

Storm period	Deficiency of soil moisture	Rainfall	*Consumptive use		Run-off	Penetration below root zone
			Transpiration	Evaporation		
1926-1927—						
Nov. 12-13	3.0	.15	.5	.2		
Nov. 24-27	3.5	2.03	.4	.5		
Dec. 3- 9	2.4	1.68	.1	.5		
Dec. 12-13	1.3	.10	.3	.1		
Dec. 18-23	1.6	1.30	.7	.5		
Jan. 10-12	1.5	.41	.4	.4		
Jan. 20-23	1.9	.95	.4	.5		
Feb. 4- 5	1.8	.93	.4	.5		
Feb. 11-18	1.8	8.77	.2	.5	.8	5.5
Feb. 22-24	0	.13	.3	.1		
Mar. 3- 5	.3	1.15	.2	.5		.2
Mar. 9-10	0	.28	.7	.3		
Mar. 28-30	.7	1.23	.4	.5		
April 10-12	.4	.94	.6	.5		
May 1	6					
Total penetration						5.7

* Transpiration and evaporation after the initial date are computed for period from second date on line to second date on line below.

TABLE 19. SUMMARY OF DETAIL CALCULATIONS OF RAINFALL PENETRATION FOR 1926-1927 IN INCHES

Basin	Seasonal rainfall	Penetration below root zone						
		Irrigated	Deciduous and vineyard	Grain and grass	Brush land	Bare land	Moist land	
							Water table 0 to 4 feet (bare land)	Water table 4 to 6 feet (with vegetation)
Upper	29.40	13.3	15.4	11.3	9.3			
	20.55	5.7		3.7	1.7			
Jurupa	14.14	0		0	0			
Cucamonga	26.98	11.1		9.1	7.1			
	20.27	6.1	7.5	4.1		13.5	14.5	8.1
Temescal	17.65	4.2	4.2	2.2				
Lower	18.16	4.9	5.2	2.9				
	14.16	1.0	1.5			7.5	8.5	3.0

TABLE 20. RAINFALL PENETRATION BELOW ROOT ZONE IN INCHES FOR SEASON 1926-1927

Seasonal rainfall	Irrigated lands (excluding deciduous and vineyards)	Deciduous and vineyards	Grain and grass land	Brush land	Bare land	Moist land	
						Water table 0 to 4 feet (bare land)	Water table 4 to 6 feet (with vegetation)
9	0	0	0	0	2.5	3.5	0
12	0	0	0	0	5.5	6.5	1.1
15	1.3	2.2	0	0	8.4	9.4	3.6
18	3.9	5.0	2.1	0	11.3	12.3	6.2
21	6.4	7.7	4.5	2.2	14.2	15.2	8.7
24	8.9	10.5	6.9	4.7			
27	11.5	13.3	9.4	7.2			
30	14.0	16.0	11.8	9.7			
33	16.5	18.8	14.3	12.3			
36	19.0	21.6	16.7	14.8			
39				17.2			

TABLE 21. SUMMARY OF DETAIL CALCULATIONS OF RAINFALL PENETRATION IN INCHES FOR 1927-1928

Basin	Seasonal rainfall	Penetration below root zone						
		Irrigated	Deciduous and vineyard	Grain and grass land	Brush land	Bare land	Moist land	
							Water table 0 to 4 feet (bare land)	Water table 4 to 6 feet vegetation)
Upper	23.39	7.0	9.7	5.0	3.0	15.7	16.7	9.0
	13.43	0	1.0	0	----------	----------	----------	----------
Cucamonga	15.63	1.1	3.0	0	0	----------	----*----	----------
	16.17	.3	3.1	0	0	----------	----------	----------
Lower	13.20	0	.8	0	0	6.8	7.8	1.8

TABLE 22. RAINFALL PENETRATION BELOW ROOT ZONE IN INCHES FOR SEASON 1927-1928

Seasonal rainfall	Irrigated lands (excluding deciduous and vineyards)	Deciduous and vineyards	Grain and grass land	Brush land	Bare land	Moist land	
						Water table 0 to 4 feet (bare land)	Water table 4 to 6 feet (with vegetation)
9	0	0	0	0	3.1	4.1	0
12	0	0	0	0	5.7	6.7	.9
15	0	2.3	0	0	8.3	9.3	3.1
18	2.5	4.9	.5	0	10.9	11.9	5.1
21	4.9	7.5	3.0	1.0	----------	----------	----------
24	7.4	10.1	5.4	3.4	----------	----------	----------

TABLE 22A. SUMMARY OF ESTIMATES OF PENETRATION

Within Valley Floor for 1926–27 and 1927–28; based on preceding values for local rainfall on varying soils and conditions of cultivation.

Basin	Area, square miles	Mean rainfall, inches	Mean penetration		Total penetration, acre-feet
			Inches	Acre-feet per square mile	
Upper—					
1926–27	124.1	21.9	7.62	407	50,700
1927–28	124.1	17.6	1.68	86	10,700
Jurupa—					
1926–27	99.1	18.4	4.17	223	22,000
1927–28	99.1	16.1	.77	41	4,100
Cucamonga—					
1926–27	268.9	22.9	8.85	472	126,700
1927–28	268.9	15.2	2.93	156	41,700
Temescal—					
1926–27	55.9	16.0	3.02	161	9,000
1927–28	55.9	14.0	1.52	82	4,600
Lower—					
1926–27	305.6	16.1	4.87	260	79,200
1927–28	305.6	15.3	4.70	251	76,900

TABLE 22B. ESTIMATE OF MEAN PENETRATION VALUES WITHIN VALLEY FLOOR, IN ACRE-FEET PER SQUARE MILE FOR VARYING MEAN RAINFALL

Mean rainfall, inches	Upper Basin, acre-feet per square mile	Jurupa Basin, acre-feet per square mile	Cucamonga Basin, acre-feet per square mile	Temescal Basin, acre-feet per square mile	Lower Basin, acre-feet per square mile
9	0	0	0	0	0
12	0	0	27	5	91
15	0	0	150	123	224
18	118	187	272	250	360
21	336	336	390	390	490
24	500	470	520	520	620

CHAPTER 5

SUMMER CONSUMPTIVE USE AND NATURAL LOSSES

For the valley floor of San Bernardino, Riverside and Orange counties the following values of transpiration and evaporation are taken. These values are based on average results obtained from field studies mostly in southern California.

1. **Irrigated Lands.**
   (a) *Transpiration*—Fifty per cent of the water applied will be lost in transpiration, within ordinary range of use.
   (b) *Evaporation*—Loss by evaporation is taken as 1 inch after each irrigation.
   (c) The remainder is deep penetration or "return waters."

2. **Irrigated Moist Lands.** Transpiration and evaporation is taken at 20 inches per season where the water plane is between 4 and 6 feet from the surface.

3. **Sandy River Beds.** On land where the water plane is within 4 feet of the surface, no transpiration is considered. Evaporation is taken at 18 inches per season.

4. **River Beds, Free Water Surface and Willows.** All losses are taken as 34 inches where the water plane is within 4 feet of the surface.

5. **Municipal Areas.** Losses are taken at 60 per cent of supply.

6. **Bare River Beds.** No losses are considered on bare river beds where the water plane is below 4 feet of the surface.

TABLE 23. CALCULATION TABLE

For consumptive use

Type of land	Duty	In acre-feet per acre			
		Transpiration	Evaporation	Consumptive use	Resulting return water
Irrigated land	2.5	1.25	.42	1.67	.83
Irrigated land	2.0	1.00	.33	1.33	.67
Irrigated land	1.5	.75	.25	1.00	.50
Irrigated land	1.0	.50	.17	.87	.13
Irrigated moist lands; water plane 4 to 6 ft. from surface		1.25	.42	1.67	
Bare river bed; water plane 0 to 4 ft. from surface		0	1.50	1.50	
River bed, free water surface and willows; water plane 0 to 4 ft. from surface				2.84	
Municipal areas	2.00			1.20	.80
Municipal areas	1.50			.90	.60

TABLE 24. DUTY OF WATER FOR VARIOUS CROPS, VALUES ADOPTED IN ARRIVING AT CONSUMPTIVE LOSS QUANTITIES

Where statistics are available over considerable areas, the local duty is adopted. For unmetered areas the following is adopted:

	Acre-feet per acre
Grain, generally unirrigated	0
Grain, if irrigated	.5
Walnuts, in general same total quantity of water as applied to citrus; number of irrigations one less thus decreasing evaporation losses	2 to 2.5
Deciduous, except walnuts	1 to 1.5
Vines	0 to 1.0
Citrus, mature trees, Riverside and San Bernardino areas	2.5
Citrus, mature trees, Ontario area	2.3
Citrus, mature trees, Orange County	2.0
Citrus, young 6 to 10 years	.75 of mature trees
Alfalfa	3.0
Olives	1.5
Truck and miscellaneous crops, Riverside and San Bernardino counties	1.5
Truck and miscellaneous crops, Orange county, including vegetables, beans, peppers, beets, tomatoes, cauliflower and cabbage, mostly in area where the water plane is 6 to 8 ft. from the surface	1.0

TABLE 25. AREA IN RIVER BEDS, FOR NATURAL LOSS COMPUTATIONS

In acres

Basin	Area covered by perennial flow	Bare sandy river beds water plane 0 to 4 feet from surface	Bare sandy river beds water plane over 4 feet from surface	Total natural river bed	Willows adjacent to river bed
Upper	26	112	2,520	2,688	400
Jurupa	65	314	293	672	1,270
Cucamonga	308	305	193	806	1,130
Temescal	0	70	700	770	0
Lower	113	100	1,129	1,342	1,300
Totals	512	931	4,835	6,278	4,100

Computed Natural Losses in River Beds During Summer Season in Acre-feet

(Using rate of 2.84 acre-feet per acre for perennial flow areas and willows, and 1 50 acre-feet per acre for bare river bed, where the water plane is within 4 feet of the surface.)

Basin	Loss on area covered by perennial flow	Loss from willows adjacent to river bed	Loss from bare sandy river beds	Total natural Loss
Upper	74	1,140	213	1,400
Jurupa	185	3,610	471	4,300
Cucamonga	875	3,210	458	4,500
Temescal	0	0	100	100
Lower	322	3,690	150	4,200
Totals	1,456	11,650	1,392	14,500

The analysis of consumptive use and natural losses has been made by two independent methods. One is derived from the subtraction of the outflow from the inflow in each basin. This difference represents the total losses in the basin, when corrected for gravel storage. The resulting quantities were shown in Table 10, page 101. The other method is to set up the acreage of various crops and the river bed areas multiplied by the loss factors given in Table 23, page 158.

In the following Table 26, the quantities determined by the second method are calculated and reconciled to the hydrographic figures of the first method.

TABLE 26. ESTIMATED CONSUMPTIVE USE AND NATURAL LOSSES BY BASINS

Upper Basin

(Exclusive of Yucaipa and Beaumont valleys)

Crop	Area in acres	Duty acre-feet per acre	Consumptive use in acre-feet per acre	Loss in acre-feet
Consumptive Uss				
Domestic	6,372	2.0	1.20	7,646
Citrus	19,909	2.5	1.67	33,248
Deciduous	1,600	1.5	1.0	1,600
Apples, cherries, etc.	600	1.5	1.0	600
Walnuts	30	2.5	1.67	50
Vines	918	1.0	.87	799
Unclassified and field crops	13,453	1.5	1.0	13,453
Natural Losses				
Perennial flow and willows	426		2.84	1,210
Bare river bed	142		1.50	213
Unirrigated moist land	2,500		2.84	7,100
Apparent natural consumptive use of unoccupied land	25,900		1.35	34,881
Total consumptive use and natural losses as determined by hydrographic study	71,850		1.4	100,800

NOTE.—The above table applies to the valley floor and is confined to lands lying below the gaging stations shown on Plate 9, page 184. In general these gaging stations are above the first point of use. The only exception is the San Timoteo gaging station, which records a net supply reaching the valley floor from Beaumont and Yucaipa valleys after this supply has been reduced by an estimated average consumptive use of 12,000 acre-feet in these upper valleys.

Jurupa Basin

Crop	Area in acres	Duty acre-feet per acre	Consumptive use in acre-feet per acre	Loss in acre-feet
Consumptive Use				
Domestic	2,910	1.5	.90	2,619
Citrus	21,903	2.5	1.67	36,578
Deciduous	1,822	1.5	1.0	1,822
Almonds, etc.	798	1.0	.87	694
Walnuts	1,012	2.5	1.45	1,467
Vines	985	1.0	.87	857
Truck	846	1.5	1.0	846
Alfalfa	2,954	3.0	2.10	6,203
Unclassified	12,190	1.5	1 00	12,190
Natural Losses				
Perennial flow and willows	1,335		2.84	3,791
Bare river bed	314		1.50	471
Apparent consumptive use of unoccupied land	14,800		1.35	19,962
Total losses, by hydrographic study	61,869		1.4	87,500

Cucamonga Basin

Crop	Area in acres	Duty acre-feet per acre	Consumptive use in acre-feet per acre	Loss in acre-feet
Consumptive Use				
Domestic	3,280	1.5	.90	2,952
Citrus	17,184	2.0	1.33	22,855
Deciduous	11,787	1.0	.87	10,255
Almonds, etc.	758	1.0	.87	659
Walnuts	4,181	2.0	1.33	5,561
Vines	31,617	.5	.50	15,808
Truck	1,540	1.5	1.0	1,540
Alfalfa	1,440	2.5	1.67	2,405
Unclassified	30,269			11,923
Natural Losses				
Perennial flow and willows	1,438		2.84	4,084
Bare river bed	305		1.5	458
Apparent consumptive use, unoccupied land	129,000		0	0
Total losses, by hydrographic study	232,799		.3	78,500

TABLE 26. ESTIMATED CONSUMPTIVE USE AND NATURAL LOSSES BY BASINS—Continued

Temescal Basin

Crop	Area in acres	Duty acre-feet per acre	Consumptive use in acre-feet per acre	Loss in acre-feet
Consumptive Use				
Domestic	1,090	1.5	.90	981
Citrus	7,193	2.0	1.33	9,567
Deciduous	929	1.5	1.0	929
Almonds, etc.	139	1.5	1.0	139
Walnuts	643	2.5	1.5	964
Vines	439	1.0	.87	439
Truck	857	1.5	1.0	857
Alfalfa	3,300	3.0	2.10	6,930
Miscellaneous	3,710	1.5	1.0	3,710
Natural Losses				
Bare river bed	70			100
Apparent consumptive use of unoccupied land	10,800		1.1	12,584
Total losses, by hydrographic study	29,170		1.3	37,200

Lower Basin

Crop	Area in acres	Duty acre-feet per acre	Consumptive use in acre-feet per acre	Loss in acre-feet
Consumptive Use				
Domestic	10,970	1.50	.90	9,873
Citrus	51,900	2.00	1.33	69,027
Deciduous	1,555	1.00	.87	1,353
Almonds, etc.	550	1.00	.87	478
Walnuts	15,400	2.00	1.33	20,482
Vines	250	.50	.50	125
Truck	5,700	1.00	.87	4,959
Alfalfa	3,000	2.50	1.67	5,010
Unclassified	58,139	1.00	.87	50,580
Natural Losses				
Perennial flow and willows	1,413		2.84	4,013
Bare river bed	100		1.50	150
Apparent consumptive use of unoccupied land	55,000			4,450
Total losses, by hydrographic study	203,977		.8	170,500

Observations On Moist Lands In Orange County. A high water table occurs on the Santa Ana River plain south and west of the 75-foot contour of surface elevation. Within this area the high water table generally stands three to eight feet below the ground surface regardless of soil type, elevation above sea level or the depth of water table as indicated by deep wells.

This investigation has observed some 100 holes bored with a soil auger in this area at intervals of two months. The number was later reduced to 50, because of rejection of poorly located holes. In general these test holes indicate that tile draining, which is almost universal in this area, acts in the anticipated way.

Soil sampling in October, 1928, indicates a low initial deficiency of soil moisture and the probability is that much of the rainfall reaches the perched water table. A general inspection of the area on October 25-26, 1928, indicated that surface evaporation at this time of the year is very limited in extent. Small areas below Talbert along the river showed indications that surface evaporation was taking place. All beans and sugar beets were harvested at this date, and the land cultivated. The mulch was generally deep and loose, indicating that surface evaporation was negligible on this land. Peppers were just being harvested and it was in some of these fields, below Talbert, that surface evaporation was indicated. The lower end of some irrigated fields showed the effect of surface evaporation coming from the perched water table.

The artesian area southwest of Wintersburg has the highest water table. Some abandoned wells are drained to the ditches. This is an area of heavy soil type and is mostly under cultivation, so that the surface evaporation is probably limited here also. Much of the uncropped land is losing water by transpiration from salt grass and weeds throughout the year as the growth was still green in the latter part of October, 1928. When the land is cropped, this loss is turned to consumptive use.

Extract from "Shape of Water Table in Tile Drained Land," Hilgardia, Univ. of Calif. March, 1928, Weir.

Investigations described more in detail were conducted in the Newhope Drainage District of Orange County during the summer of 1926.

This District contains about 4000 acres of tile drained irrigated land and is situated on the west side of the Santa Ana River, directly west of the city of Santa Ana.

The soil of this area is Hanford sand and fine sandy loam. This is a recent alluvial deposit which is deep and readily permeable to roots and water.

The drainage system consists of lines of tile located in roughly parallel, north and south lines, about one-quarter mile apart. The tile used in this system vary in size from 30 inches in diameter at the lower end of the main line to 8 inches in diameter at the upper ends of laterals. The average depth of drain is between 8 and 9 feet. The water table has been quite generally lowered over the district, as indicated by measurements taken both before and after the drainage system was installed. In many places this has amounted to 3 feet or more.

This District appeared to have almost ideal conditions for the study of water table profile shapes because the soil is fairly uniform in texture, depth and general characteristics. The drains run principally all in one direction and far enough apart to provide for full development of water table profiles. The drains are also deeper than usual and the tract is satisfactorily drained.

* * * * * * *

Summary and Conclusions—From the data which were obtained under these widely different soil conditions and widely different spacing and depth of tile, it appears reasonable to conclude that:

1. The water table between lines of tile is practically a straight line, except within a very short distance of the tile.

2. The depth of tile or the spacing between lines of tile does not materially alter the shape of the water table.

3. The water table under certain conditions may stand above a tile line at points directly over it and yet the drainage be efficient and the tile lines only partially filled with flowing water.

4. Because of the flatness of the water table, it would appear probable that the major part of the lateral adjustment in the water table, due to the removal of water by a drain, takes place below the flow line; and in that portion of the water table above the flow line the movement is largely vertical. It seems logical that the lateral gradient in the surface of the water table must be greater than has been shown in these profiles before there is a significant lateral movement toward a drain in that portion of the water table which is above the flow line.

5. The depth of tile rather than the spacing between tile lines is the more important feature affecting the efficiency of a drainage system.

6. To obtain the same efficiency (that is, the same lowering of the water table) in areas where the vertical pressures differ, the tile must be either deeper or closer together in the case of the greater pressure.

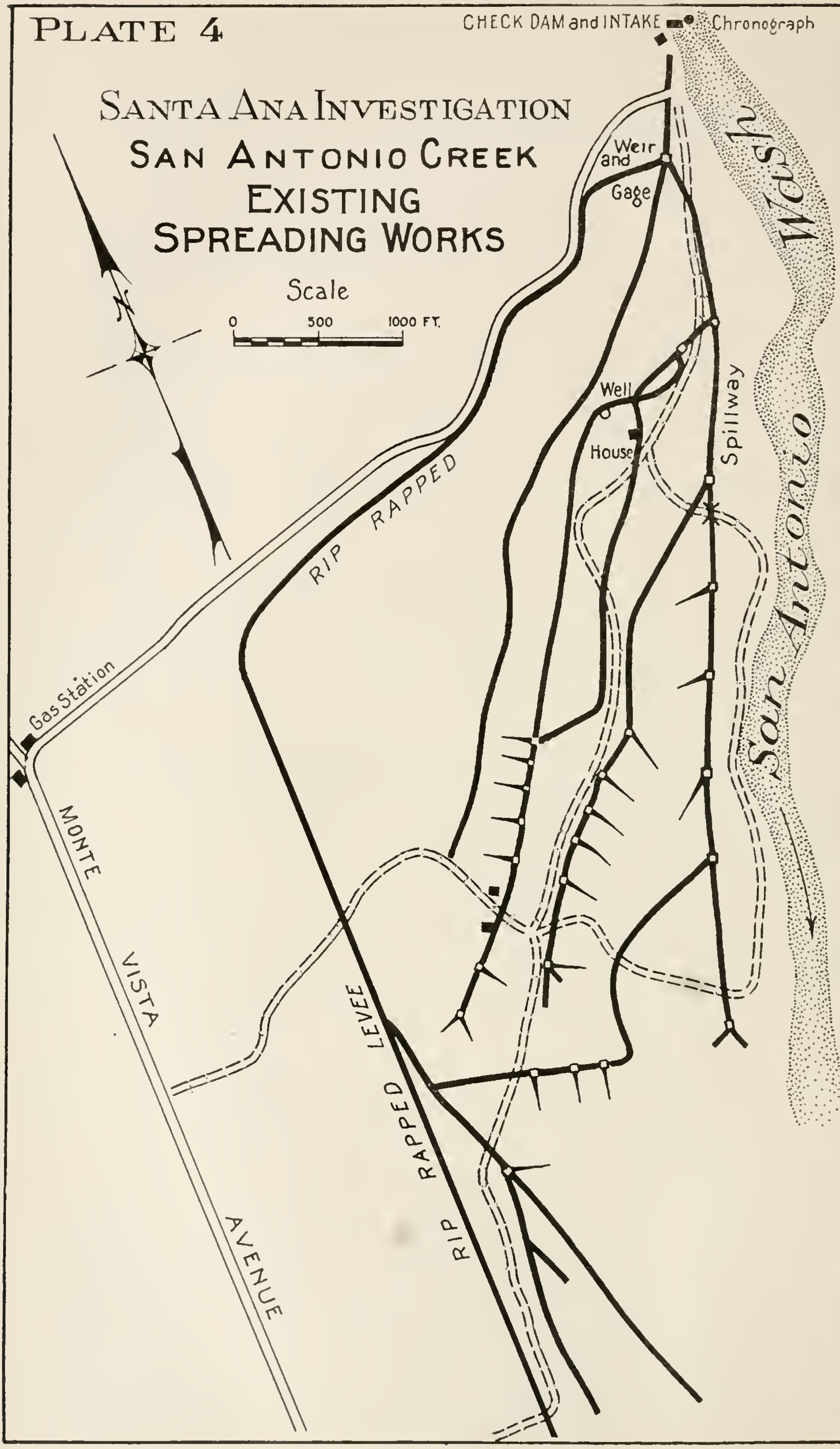


PLATE 4
SANTA ANA INVESTIGATION
SAN ANTONIO CREEK
EXISTING
SPREADING WORKS
Scale
0 500 1000 FT.
N
CHECK DAM and INTAKE
Chronograph
Weir and Gage
Well
House
Spillway
San Antonio Wash
RIP RAPPED
Gas Station
MONTE VISTA AVENUE
LEVEE
RIP RAPPED

CHAPTER 6

ABSORPTION OF WATER BY GRAVELS; EXISTING SPREADING WORKS

Absorption.

The determination of the data of absorption in gravels has been frequently published as a per cent of loss. In order to determine the required area of spreading grounds, the rate of absorption per acre in second-feet or in vertical feet of water per day is needed. In the following table are collected measurements of the rate of absorption in which the area also was ascertained.

TABLE 27

Place	Character of material	Observed loss in second-feet	Area in acres	Rate of absorption	
				Second-feet per acre	Depth of water in 24 hours
San Antonio river cone at Upland. San Antonio Water Co. ditch February, 1928. Measured by Santa Ana investigation	Gravel and sand	1.2	.85	1.4	2.8
Santa Ana River in lower canyon near Yorba, February 24, 1928. Measured by Santa Ana Investigation	Sand	136.0	150.0	.9	1.8
San Gabriel River (from Bulletin No. 5. Div. of Water Rights, 1927.) Measured in April and May, 1926					
(a) Above Foothill Boulevard	Boulders, gravel and sand	32.0	36.0	.9	1.8
(b) Below Foothill Boulevard	Small boulders, gravel and sand	76.0	51.0	1.5	3.0
(c) Upper El Monte Island	Gravel and sand	157.0	69.0	2.28	4.5
(d) Above Valley Boulevard	Small gravel and sand	31.0	6.4	4.76	9.5
Santa Ana River, cone at canyon mouth. Water spreading by Water Conservation Association from Trans. Am. Society C. E. Vol. 82, page 802, 1918 Sonderegger	Boulders, gravel and sand			3.42	6.8
San Francisquito Creek, (from report of Div. of Water Rights Jan. 27, 1927, observations Sept. 16, 1926.)					
6.5 miles above mouth	Gravel and sand	12.1	5.4	2.24	4.5
5.5 miles above mouth	Sand	41.7	8.7	4.8	9.6
4.0 miles above mouth	Sand	46.2	11.2	4.1	8.2

Existing Spreading Works.

The following is a list of localities where spreading is practiced in Santa Ana watershed:

Barton Flat—Water Conservation Association
Mentone—Water Conservation Association
Mill Creek—East Lugonia Water Company and City of Redlands
City Creek—City Creek Water Company
Devil Canyon—City of San Bernardino
Lytle Creek—Lytle Creek Conservation Association
Lower Lytle Creek—Lytle Creek Conservation Association
Day Canyon—Etiwanda Water Company
Cucamonga Creek—Cucamonga Water Company and others
Cucamonga Cone, San Antonio water imported—San Antonio Water Company
San Antonio Creek—Pomona Valley Protective Association
Temescal Creek—Temescal Water Company
Edgar Canyon, Beaumont—Beaumont Irrigation District
Santiago Creek—Serrano and Carpenter Irrigation District

San Antonio Creek Spreading Works. "The water is spread over the boulders, gravel and soil below the canyon with slope of 200 to 100 feet per mile. An association has been organized among the water companies and individual well owners, of which there are many in Pomona Valley, to conduct the work, and the cost is borne by the members in the proportion that water is used by them. At first the headworks were of a temporary kind and much work had to be done when the floods came to divert the water. Three main ditches are used. Later concrete headgates were placed on these and a concrete dam was placed across the stream channel at the upper gate. * * * A stream of about 30 second-feet is diverted at the upper headgate and less at the lower gates. Streams of 20 or 30 miner's inches are taken from the main ditches and the water is induced to cover as much ground surface as possible. The grades and alignments of the ditches conform to the topography of the land and the more checks to form pools the better for absorption. * * * The association owns most of the land on which it operates. Willis S. Jones, engineer for the association, states that the soil takes up 100 miner's inches or two second-feet per acre continuously during the several weeks of the flood season. A test made by Mr. Jones and the writer shows that the rate of absorption sometimes reaches double that figure. Two men are employed throughout the season and an additional force on occasions. The cost of operation has been 30 cents per acre foot. The effect of spreading water has been very marked on a tunnel and wells a few miles below the spreading ground. The flow of these increases in the late summer. The effect of the work reaches wells lower in the valley the second year. Except in years of unusual run-off no water is allowed to flow beyond the limits of Pomona Valley." Preliminary Report on Conservation and Control of Flood Water in Coachella Valley. State Department of Engineering, Bulletin No. 4, 1917, Tait.

"Conservation work was commenced in a desultory way in 1895, when the owners of the Mountain View tunnel, east of Claremont, spread flood water above the tunnel to increase the flow. In 1896, an employee of Fleming & Beckett, owners of the present Consolidated Water Company's tunnel at Indian Hill, north of Claremont, suggested diverting the flood water of San Antonio stream to replenish the tunnel. This was done, and from year to year, water was diverted by both the above interests. At first water was spread near the tunnel, later at points farther up on the cone nearer the mouth of the canyon.

"In December, 1908, the larger water interests got together and, in January, 1909, the Pomona Valley Protective Association was incorporated, embracing 14 corporations and 32 individuals, representing 1800 miner's inches of water. This association purchased about 1000 acres of land for conservation purposes along the channels of the San Antonio wash and Thompson Creek and, together with two other members of the league, control 4½ miles of the San Antonio stream channels.

"The lands thus secured along San Antonio Creek enable the association to spread large quantities of the San Antonio flood water and some of the flood waters of Williams Canyon and Thompson Creek.

* * * * * * *

"During the height of the flood in 1917, 9000 inches of dirty water were turned out at the dam and led into 2 or 3 ditches leading to the return channel. While it was raining with great intensity, the amount of water reaching the return channel at the bridge on the diagonal road 1 mile away was less than 50 inches. Not only the entire 9000 inches but, in addition, all the rain that was falling on the sage-covered washes was absorbed. On the other hand, every cultivated orchard was discharging large volumes.

"In company with Prof. Slichter on one occasion, Prof. C. E. Tait, U. S. Government Irrigation Engineer, on another, the rate of absorption on these lands was tested and found to be as high as 1 miner's inch per ten square feet of land covered. This is nearly the highest known rate of absorption.

* * * * * * *

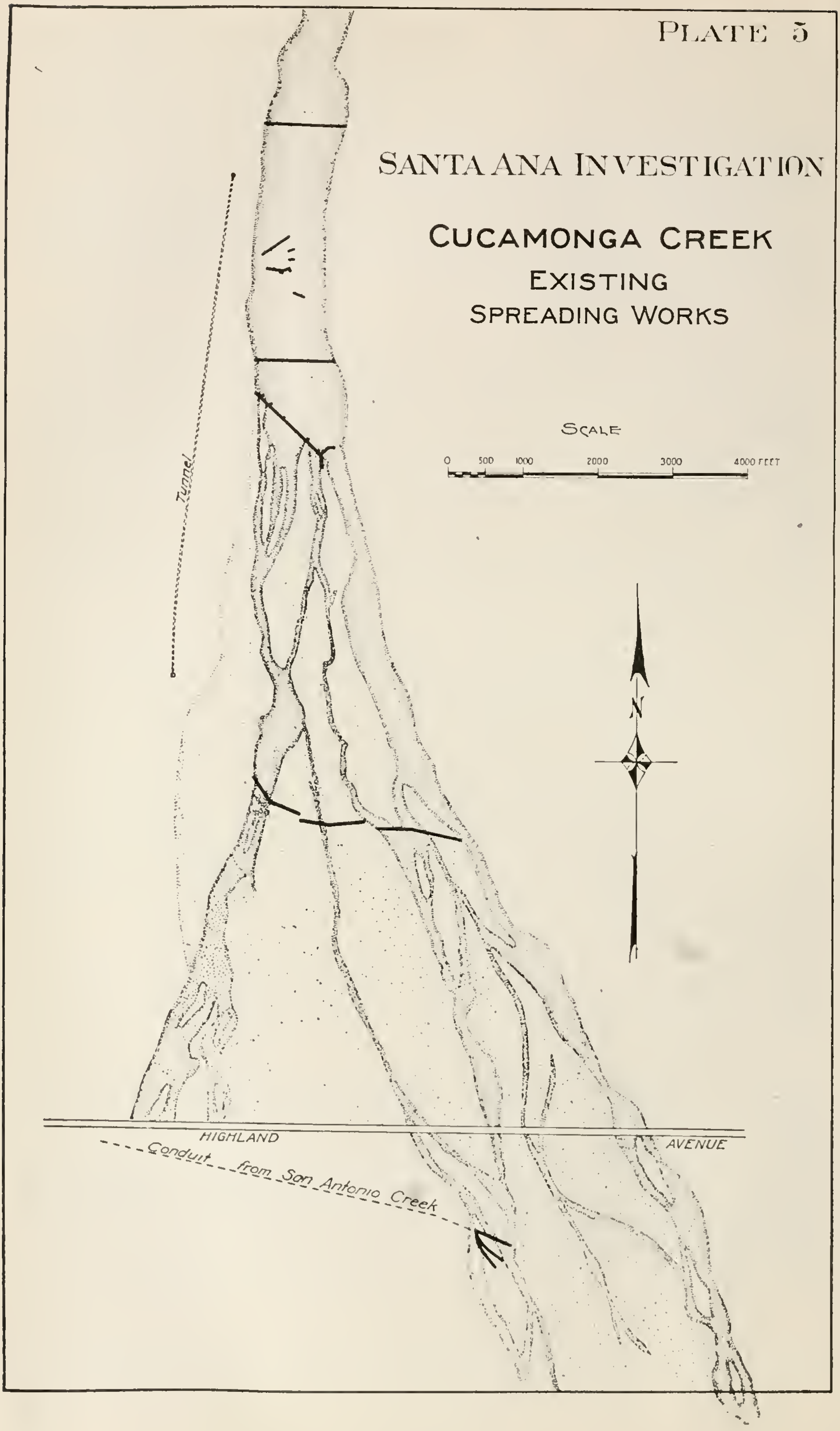
"The flood of 1916 destroyed the concrete apron at the diversion dam at the mouth of the canyon. This has been replaced by a much stronger structure consisting of a foot wall of cyclopean masonry, individual boulders weighing from one-half ton to two and one-half tons, thoroughly embedded in cement concrete, making a fall 70 feet long across the channel, 6 feet high, and 8 feet wide on the base. Above this, a space 40 feet by 19 feet has been covered with 40-pound steel rails, placed 6 inches center to center and anchored with $\frac{7}{8}$-inch bolts 12 inches long, all embedded in concrete. Thus anchored, it is believed that the structure will withstand the action of greater floods than those of 1914 and 1916.

Briefly the conservation work now consists of:

1. Protection wall 75 feet long at the mouth of the canyon, through which is a gate for diverting water.
2. The diversion dam, approximately 150 feet long, across the main channel.
3. Three gates and sluiceway from the dam.
4. A side channel 30 feet wide, capacity 500 to 700 second-feet.
5. Seven main laterals protected with concrete headgates cover about 400 acres. In addition there are miles of smaller ditches.
6. A return channel around the entire upper spreading district to return any unabsorbed diverted water to the main stream.
7. Two shafts for conservation.
8. Three main roads and three branch roads radiating from the dam, reaching every part of the spreading grounds.
9. Permanent camp, consisting of one corrugated iron house (three rooms), two sheds, and two tents.
10. The Fleming Dam near the base line is 1760 feet, through which are three openings controlled by gates for distributing water near the Mountain View tunnel." Trans. Southern California Sect., Am. Soc. C. E. Vol. 1, Bul. No. 4, 1919, Jones.

The San Antonio spreading works are at this time being extended in cooperation with Los Angeles County Flood Control. The present situation is shown in Plate 4, page 164. The concrete weir is illustrated in Fig. 43, page 182.

PLATE 5


SANTA ANA INVESTIGATION
CUCAMONGA CREEK
EXISTING
SPREADING WORKS
SCALE
0 500 1000 2000 3000 4000 FEET
N
Tunnel
HIGHLAND AVENUE
Conduit from San Antonio Creek

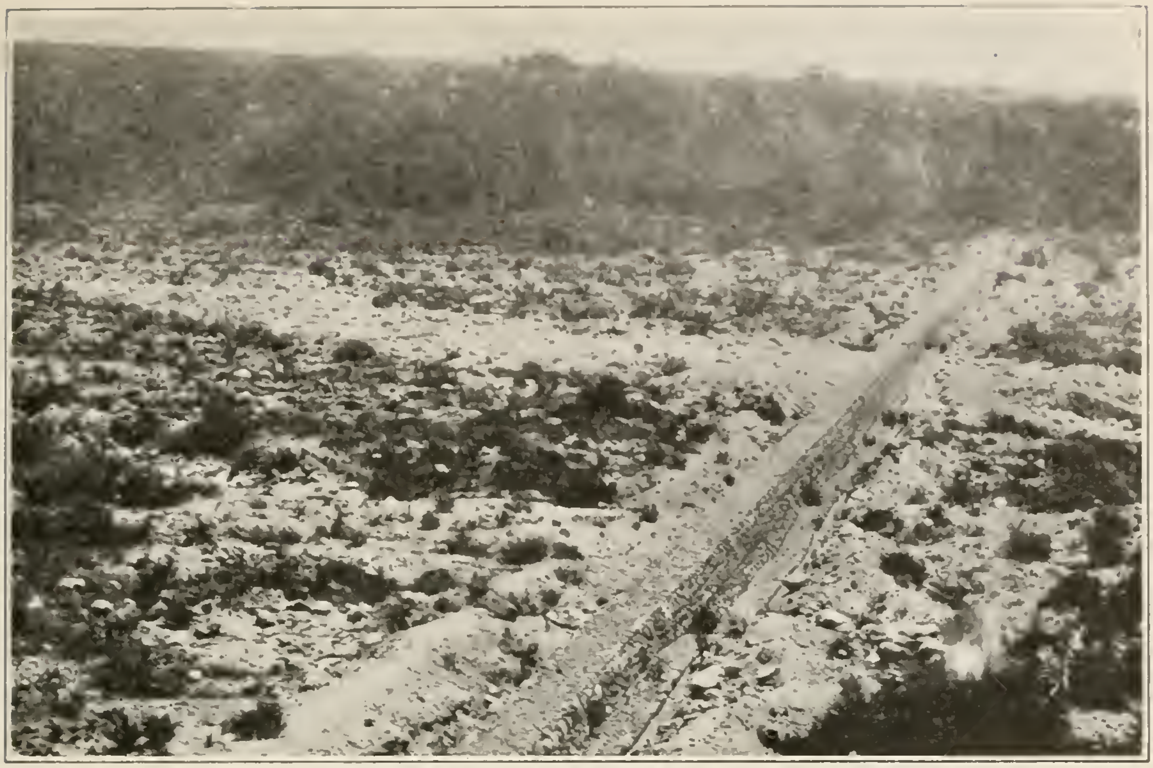


FIG. 37—Cucamonga Water Company. Spreading dam on Cucamonga Creek. This dam is at right angles to the stream, and is the middle cross wall of the system.

FIG. 38—Cucamonga Water Company. Diagonal spreading dam one-half mile below dam in Fig. 37, showing the outlets to supply the spreading ground.

Cucamonga Spreading Works. Spreading on Cucamonga Cone was practiced on a small scale from 1908–1924. In 1925, major works were begun by the San Antonio Water Company by the construction of a diagonal rock wall, shown in Plate 5, page 168. The upstream wall, a long check dam, was built in 1926–27. The middle cross wall was built in 1927–28.

The upstream check dam was filled with debris completely to its 6-foot height in the winter of 1925–1926. This dam stood successfully the flood of 1927, the water pouring over in a continuous thin sheet. Toward the last of the storm, some damage and settlement occurred at one section.

Mr. Ralph Shumaker, the engineer and designer of this system, concludes that the capacity of the diagonal wall for distribution and diversion to spreading, is 1 second-foot per linear foot, or 800 second-feet for the 800-foot wall.

PLATE 6

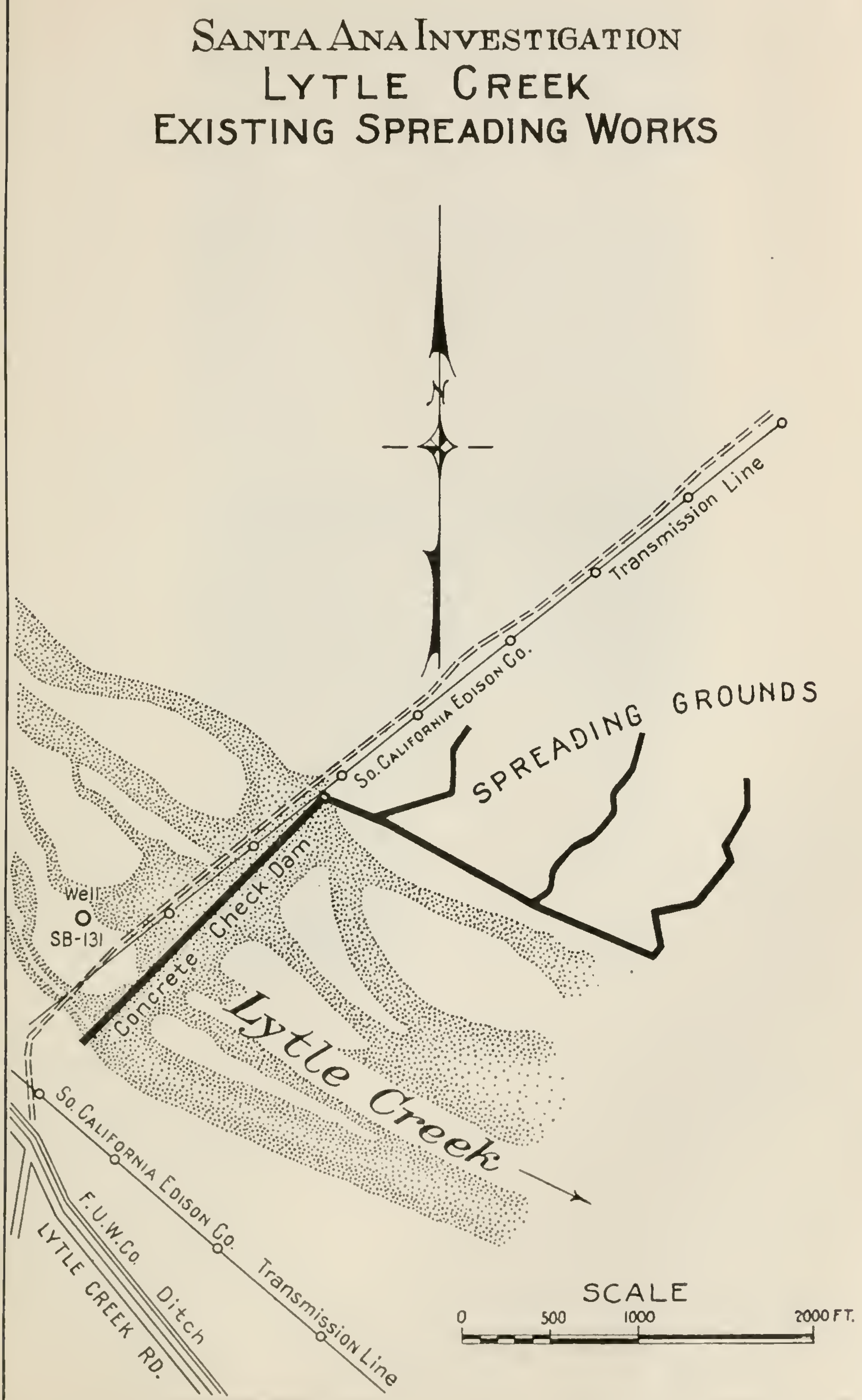

SANTA ANA INVESTIGATION
LYTLE CREEK
EXISTING SPREADING WORKS
N
So. California Edison Co.
Transmission Line
SPREADING GROUNDS
Well
SB-131
Concrete Check Dam
Lytle Creek
So. California Edison Co.
Transmission Line
F.U.W.Co.
Ditch
LYTLE CREEK RD.
SCALE
0
500
1000
2000 FT.

FIG. 39—Lytle Creek spreading and diversion dam. Intake in the distance.

FIG. 40—Lytle Creek spreading and diversion dam. Flood on April 6, 1926.

Lytle Creek Spreading Works. Spreading has been practiced on Lytle Creek since 1912. In 1925–26 a concrete dam was built by the Lytle Creek Protective Association, at the mouth of the canyon. This work was 1941 feet long, $1\frac{1}{2}$ feet wide on top and 14 feet in maximum height above the stream bed. The downstream slope is vertical and the upstream slope is $\frac{1}{2}$ to 1.

The intake to the spreading ground has a capacity of 240 second-feet, when the water is to the top of the dam, and supplies 5000 lineal feet of ditches. The area of spreading ground is 1000 acres.

Opposite the Fontana power house the waste water not needed for irrigation in winter is turned back into Lytle Creek and spread. This point is five miles below the concrete dam.

PLATE 7

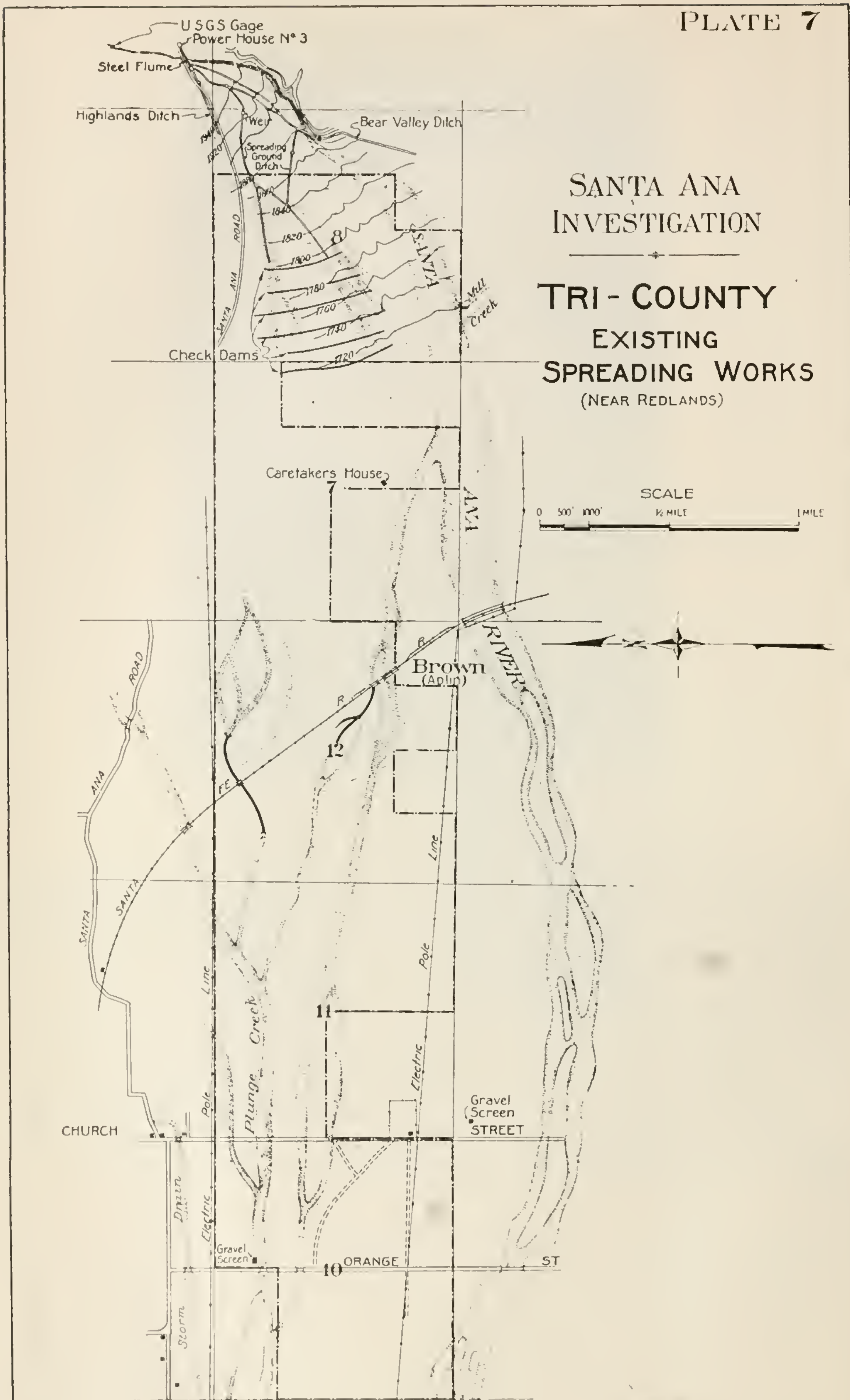

SANTA ANA
INVESTIGATION
TRI - COUNTY
EXISTING
SPREADING WORKS
(NEAR REDLANDS)
SCALE
0 500' 1000' ½ MILE 1 MILE
U S G S Gage
Power House N° 3
Steel Flume
Highlands Ditch
Weir
Bear Valley Ditch
Spreading Ground Ditch
Check Dams
Caretakers House
Mill Creek
SANTA ANA RIVER
SANTA ANA ROAD
Brown
(Aplin)
Plunge Creek
Pole Line
Electric Pole Line
Gravel Screen
CHURCH STREET
ORANGE ST
Storm Drain
8
7
12
11
10
1720
1730
1760
1780
1800
1820
1840
1860
1880
1920
1940

FIG. 41—Tri-Counties Works on Santa Ana River. Wire wall diversion dam.

FIG. 42—Tri-Counties Works on Santa Ana River. A settling basin.

Water Conservation Association Works at Mentone. The Water Conservation Association began spreading water on the debris cone of the Santa Ana River in 1911. It secured the withdrawal of approximately 1100 acres of government land by an act of congress dated February 20, 1909, and has since acquired additional land by purchase, until it now owns and controls approximately 3000 acres of land.

The association has constructed three substantial concrete headgates for the diversion of water from the Santa Ana River, and has one other intake, and through these four intakes it has a capacity of 20,000 miners inches, or 400 second-feet. Diversions from the river so far have been made by loose rock dams, excepting one which has a Pratt wire dam across the main channel of the river.

About 1500 acres of land under control of the association is actually used for sinking of water, and experiments have shown that 3.4 second-feet can be sunk continuously per acre on this loose gravel and boulder formation. It has been found impracticable to divert water from the main stream during times of high water, as it is impossible to maintain the dams, and for the further reason that during such periods of high water there is a large amount of silt in suspension in the water which, if diverted onto the gravel beds, would have the effect of silting up the interstices and rendering such areas valueless for the sinking of water.

The amounts sunk and spread by the association for the different years are as follows:

Season	*Acre Feet*	*Season*	*Acre Feet*	*Season*	*Acre Feet*
1911-12	11,643	1917-18	4,398	1923-24	3,832
1912-13	3,286	1918-19	4,920	1924-25	0
1913-14	35,322	1919-20	6,063	1925-26	9,276
1914-15	28,402	1920-21	8,684	1926-27	14,275
1915-16	11,537	1921-22	81,196	1927-28	1,205
1916-17	6,726	1922-23	19,353		

The location of the sinking of this water is approximately five miles easterly and 500 feet in elevation above the San Bernardino artesian basin.

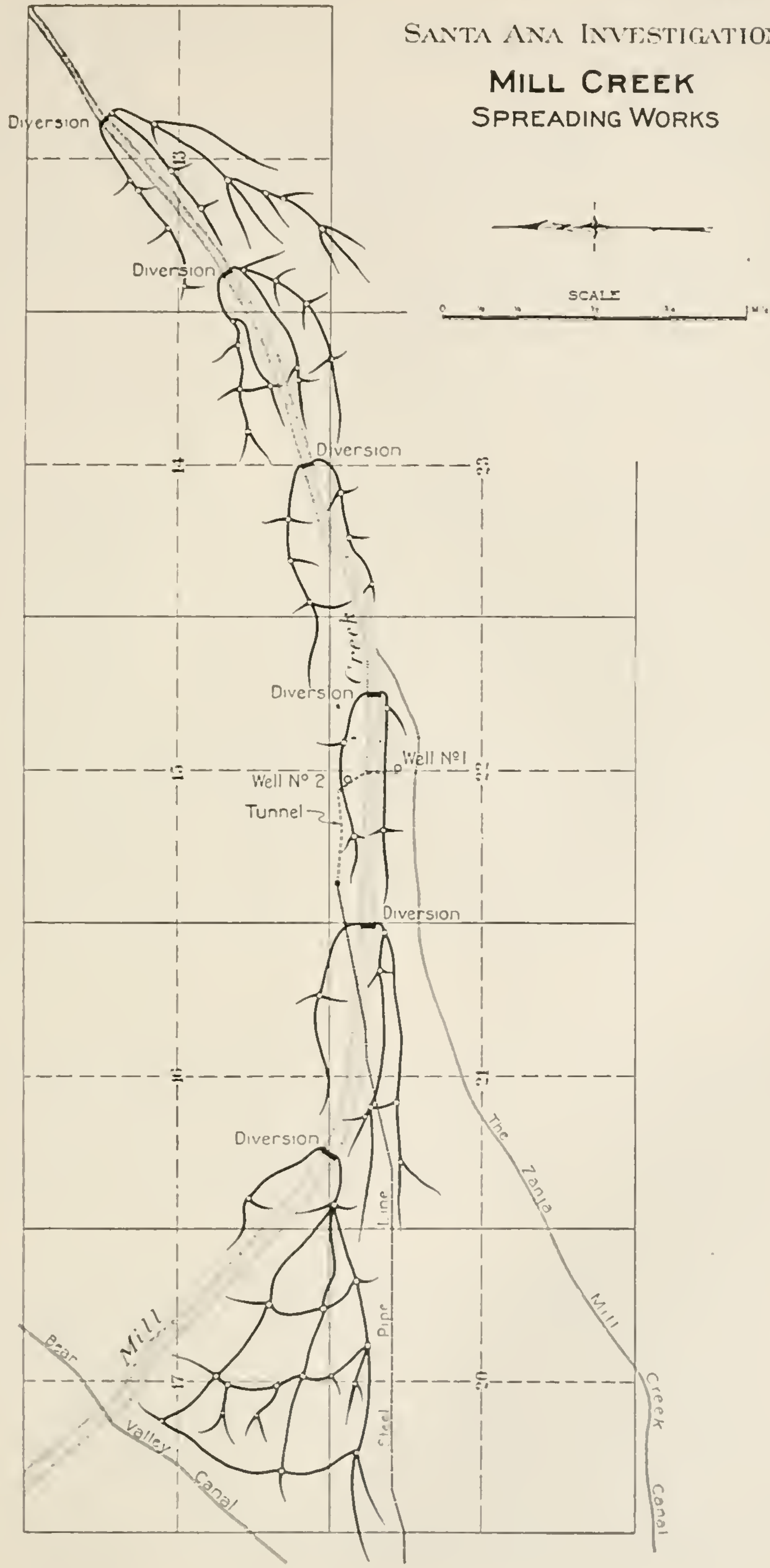
A chart published by the Water Conservation Association shows the average water pressure above the tops of seven artesian wells in this basin, to have been 33.49 feet in 1922, and 39.67 feet in 1925. This rise in pressure is ascribed by the association to the large amount spread, 81,000 acre-feet, in 1921–22.

PLATE 8

SANTA ANA INVESTIGATION

MILL CREEK

SPREADING WORKS



Mill Creek Spreading Works. Spreading has been practiced on the gravels of the Mill Creek debris cone since 1910. The spreading grounds consist of approximately 1200 acres, either owned or leased for spreading purposes by the East Lugonia Mutual Water Company and the city of Redlands.

The conservation works consist of taking water from the main channel by means of 8 diversion dams, all of these dams being of temporary construction. From them, ditches are carried into the gravel on both sides of the main channel. The waters spread are collected, in part, by tunnels traversing under the spreading grounds. These tunnels yield an average of six second-feet.

There are also a number of pumping plants on this debris cone which are supplied with water from this conservation work.

The maximum water spread on this cone in a single season has been 26,000 acre-feet.

"**Water Spreading on Santiago Creek.** It is claimed that water spreading was begun on a small scale on Santiago Creek by the Irvine Ranch Company in 1896 and, if this is correct, it appears that the practice originated on that stream. The work was taken up on a larger scale in 1910 by the Carpenter Water Company, the Serrano Water Association and the Irvine Ranch Company, acting jointly. The two first mentioned obtain their irrigation supply from a submerged dam near the mouth of the canyon, and in order that the work may be of benefit to them it must be conducted above the dam and in the canyon. Although the canyon is not wide, it has been possible to obtain three tracts of land giving a total of 1100 acres and, of this area, about 800 acres are actually covered with water. The working season generally covers three to five months, during the spring. A maximum of about 140 second-feet has been used, of which only about 50 second-feet has been in one ditch. The operating cost consists mainly of the wages of one man for the entire season and of one or two helpers during a part of the time.

* * * * * * *

"A total of $21,000 has been spent on ditches, levees and gates.

"The president of the Joint Association, under which the work is conducted, states that, when beginning to apply the water, one acre will take up five second-feet for three days, but that after the ground has become saturated the rate of absorption becomes less; also that the system is capable of handling 300 to 400 second-feet continuously throughout the season.

"The method of laying out the grounds and of applying the water differs from that on Santa Ana River and San Antonio Creek. The water is carried in ditches to the grounds, where it is held by levee checks three feet high and located on contours from 200 to 500 feet apart, depending upon the slope. The ends of the levees are turned up the slope, in such a way as to basin the water. In the first work, concrete overflows with control gates were placed at the middle of each levee and the water was run from each check to the next succeeding lower one. In the later work no overflows have been provided, but the ends of the levees are riprapped with boulders around which the water flows to the lower basin, the levees being staggered. * * *

Little trouble has been experienced with silt, but the first flood water is not used. A considerable quantity of sand has been deposited in the main ditches." Trans. Southern Calif. Sect., Am. Society C. E. Vol. 1, Bulletin No. 4, 1919, Tait.

TABLE 28. ACREAGE IN RIVER BEDS CLASSIFIED FOR USE IN DETERMINING ABSORPTION

In acres

Basin	Area covered by perennial flow	Sandy river bed, water plane 0 to 4 ft. below surface	Sandy river bed, water plane over 4 ft. below surface	Total natural wet and dry river bed	Flood of 1927 Total area submerged, water plane 0 to 4 ft. below surface	Flood of 1927 Total area submerged, water plane over 4 ft. below surface
Upper	26	142	2,520	2,688	221	1,782
Jurupa	65	314	293	672	1,145	0
Cucamonga	308	315	193	806	606	953
Temescal	0	70	700	770	0	191
Lower	113	100	1,129	1,342	575	1,895
Totals	512	931	4,835	6,278	2,547	3,821

CHAPTER 7

RATE OF MOVEMENT OF UNDERGROUND WATERS

The principal writer on underflow theory and actual measurement is Charles S. Slichter, University of Wisconsin. The following digest from publications give the Slichter laboratory and field results. Two determinations by this investigation are also described. In W. S. P. No. 140, U. S. Geological Survey (1905) page 11, Slichter defines the transmission constant "k" as "the quantity of water in cubic feet, that is transmitted in one minute through a cylinder of soil one foot in length and one square foot in cross-section under a difference of head of one foot of water."

Page 11—"The capacity of any sand or gravel to transmit water can be expressed by the transmission constant."

Page 12—"Transmission constants or "k" (theoretical values from laboratory experiments.)"

Dia. of grain in m. m.	*Kind*	*Porosity* 32 *per cent*	*Porosity* 34 *per cent*
.03	Silt	.000364	.000446
.07	Very fine sand	.001983	.002430
.15	Fine sand	.009120	.01115
.35	Medium sand	.04960	.06075
.75	Coarse sand	.2278	.2785
3.00	Fine gravel	3.640	4.460

Page 48—"Rate varies directly as the head."

Page 54—"The cross-section of the alluvial deposits at the narrows of the Hondo and San Gabriel is about 10,000 feet wide and probably does not exceed 600 feet in depth. If we assume that the porosity of the underflow gravel is 33 per cent and that the average velocity of the ground water is 10 feet a day, the resulting estimate of the amount of water which passes underground through the narrows is 230 second-feet. * * * This is undoubtedly a maximum estimate * * * 4 feet a day may be assumed as a fair minimum estimate of the average velocity. This would correspond to a total underflow of 92 second-feet."

Page 63—(Mohave, Victorville)—"Taking Schuyler's figures for the area of the cross-section of the gorge, 4160 square feet, and assuming a mean velocity of 50 feet for 24 hours and estimating the porosity of the gravel at 33 1/3 per cent, the total underflow will be found to be less than one second-foot. * * * The gradient of the water plane is almost exactly 20 feet to the mile."

The following quotations are from U. S. G. S., W. S. P. No. 112 (1905), Homer Hamlin:

Page 29—"Porosity of Tujunga sands in San Fernando Valley is from 32 to 42 per cent and effective diameter ranges between .055 and .43 m.m."

Page 51—"Huron Street Section, Los Angeles River."

Western Gravel Bed:

Total cross section	17,000 square feet
Porosity assumed	25 per cent
Average velocity 20.6 times 80 per cent for obliquity	16.5 feet per day
Discharge	70,040 cubic feet per day

Eastern Gravel Bed:

Total cross section	30,700 square feet
Porosity	25 per cent
Average velocity corrected	15.45 feet per day
Discharge	18,578 cubic feet per day

From U. S. G. S., W. S. P. No. 446, Lee (1919), page 148

Bonsal Section, San Luis Rey River:

Slope of water table——12 feet per mile
Velocity of underflow——5.14 feet per day
Discharge ——0.47 second-foot

Lytle Creek.—A tunnel near the mouth of the canyon a mile long driven upstream, intercepts the underflow to a depth of 90 feet. The width of the channel is estimated at 400 feet with an average depth of 70 feet. The discharge measured in 1928 was 3.1 second-feet. These figures give the following results:

Discharge ——3.1 second-feet
Gross area ——28,000 square feet
Effective area using 33 per cent porosity——9,300 square feet
Velocity through effective area——29 feet per day
Gradient ——3.8 per cent
"K" transmission constant as defined by Slichter——0.19

Santa Ana River at Tidewater.—In the study of escape into the ocean, given in section 8, page 205, the following was determined from pumping information:

Discharge ——3.4 second-feet
Gross area ——800,000 square feet
Effective area using 33 per cent porosity——267,000 square feet
Velocity through effective area——1.1 feet per day
Gradient ——0.19 per cent
"K" transmission constant as defined by Slichter——0.13

TABLE 29. SUMMARY OF UNDERFLOW DETERMINATIONS

Place	Cross-section square-feet	Porosity assumed per cent	Vel. through effective area for this porosity in feet per day	Gradient	Resulting transmission constant "K"	Discharge, second-feet
San Gabriel:						
Maximum estimate	6,000,000	33	10.0	.27	.85	230.0
Minimum estimate	6,000,000	33	4.0	.27	.34	92.0
Mohave	4,160	33	50.0	.38	3.42	.9
Los Angeles:						
West section	17,000	25	16.5	.38	.74	.8
East section	30,700	25	15.5	.38	.72	1.4
San Luis Rey	23,700	33	5.14	.23	.50	.5
Lytle	28,000	33	29.0	3.80	.19	3.1
Santa Ana:						
At tidewater	800,000	33	1.1	.19	.13	3.4

CALCULATIONS OF UNDERFLOW

Santa Ana River at Mentone:

Cross sectional area——48,000 square feet
"K" transmission constant taken as in Lytle Creek——0.19
Gradient ——3.1 per cent
Discharge ——4.9 second-feet

Santa Ana River at Pedley Bridge:

Cross sectional area ——18,000 square feet
"K" transmission constant taken as on San Luis Rey——0.50
Gradient ——0.33 per cent
Discharge ——0.45 second-feet

Santa Ana River U. S. G. S. at Prado:

Cross sectional area (at Oil Well Site)——73,000 square feet
"K" transmission constant as on San Luis Rey——0.50
Gradient ——0.26 per cent
Discharge ——1.4 second-feet

There is rising water between U. S. G. S. Gaging Station at Prado and Oil Well Site in the winter reaching 10 second-feet. An amount of 5 second-feet is added to allow for average rising waters. The total taken for underflow at U. S. G. S. Gaging Station at Prado is 6.4 second-feet or 5000 acre-feet annually.

FIG. 43—State Gaging Station, on San Antonio Creek near Claremont.

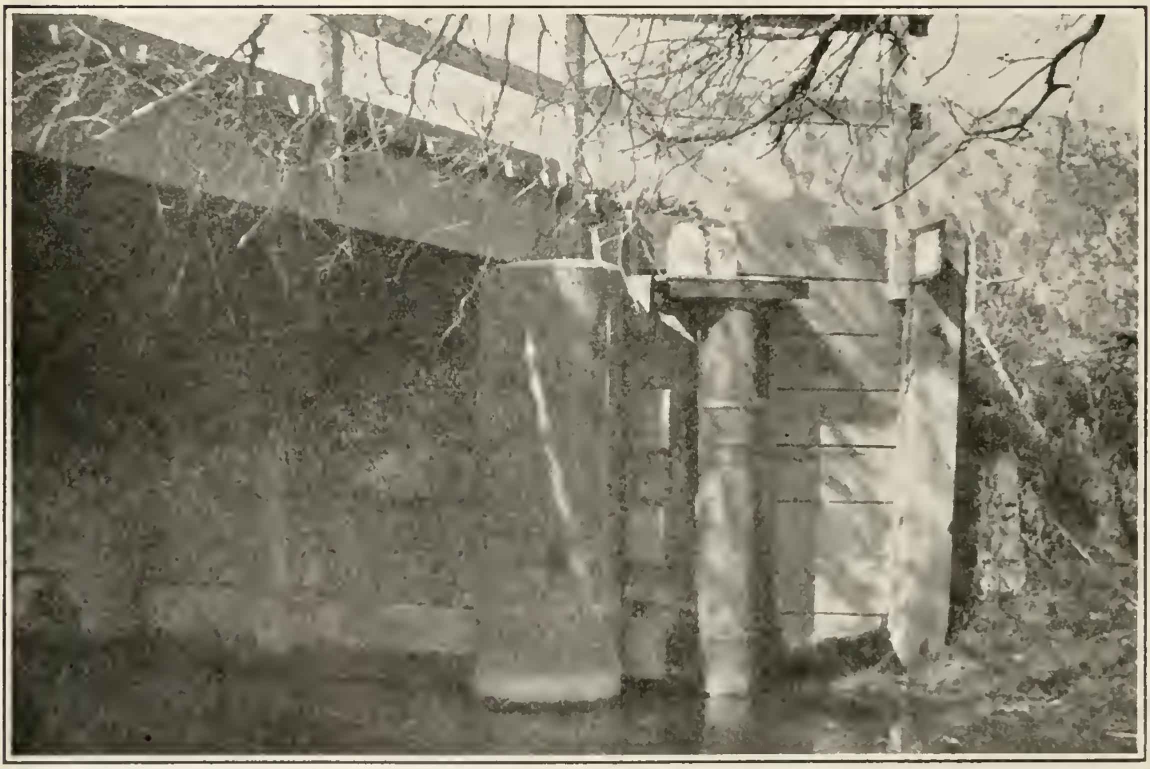


FIG. 44—State Gaging Station, on Chino Creek near Chino.

FIG. 45—State Gaging Station on Cucamonga Canyon near Upland.

FIG. 46—State Gaging Station on Day Canyon near Etiwanda.

CHAPTER 8

HYDROGRAPHY

General. The hydrography of the Santa Ana River is complicated. Numerous mountain streams flow into the valley floor, in various basins. Their waters are partly absorbed in the gravels, and partly diverted. A portion only passes on to the next basin. There are five successive basins, each with a broad gravel area, closed by a barrier at the lower end.

The outflow from a basin in any year is not equal to the sum of the surface streams entering its valley floor, because in passing across the valley floor some of the inflow is detained as underground storage and some is consumed. These factors decrease the volume of inflow, while rainfall on the valley floor percolates and adds to the volume of the outflow.

To arrive at the relation of the basins requires a complete tabulation of all the streams not only where they appear from the mountains, but also at various strategic points in the lower stream.

The U. S. Geological Survey has maintained for long periods a group of stations from Lytle to Mill creeks, and two stations on the lower Santa Ana, for a short period.

The Seasons, 1926-27 and 1927-28. The field plan of this investigation was to make an intensive measurement for the season 1927-28, securing actual records on all significant water courses. In addition stations were established on the middle Santa Ana River, and at the mouths of Temescal and Chino creeks. A complete series of stations measured the escape into the ocean.

Method Used in Restorations of 1926-27 Run-off. On all gaging stations in service in 1926-27, the run-off per square mile for this season was tabulated. The run-off was analyzed into two components, the perennial flow and the storm flow. Perennial flow is defined as "that portion of the run-off which goes on whether it storms or not." It is practically equivalent to "low water flow," or "constant flow" or "seepage flow." Storm flow as here used is defined, as "that portion of run-off over and above perennial flow." Storm flow is indicated by direct rises in the normal volume of the stream. Study has shown that storm flow varies in a similar manner in adjoining watersheds.

The perennial flow component of run-off of streams not measured in 1926-27 was taken as equal to the perennial flow actually determined in 1927-28. The unknown storm flow component was estimated from that of adjoining measured streams of similar regimen. The perennial flow so ascertained, added to the estimated storm flow is taken as the run-off for restoration of streams unmeasured in 1926-27.

The run-off, and its components, perennial flow and storm flow, were reduced to acre-feet per square mile to facilitate calculation.

The known storm flow of streams measured in 1926-27 is tabulated in Table 30. In this table the streams are arranged in the order of the highest altitude of their watersheds and by maximum gradient.

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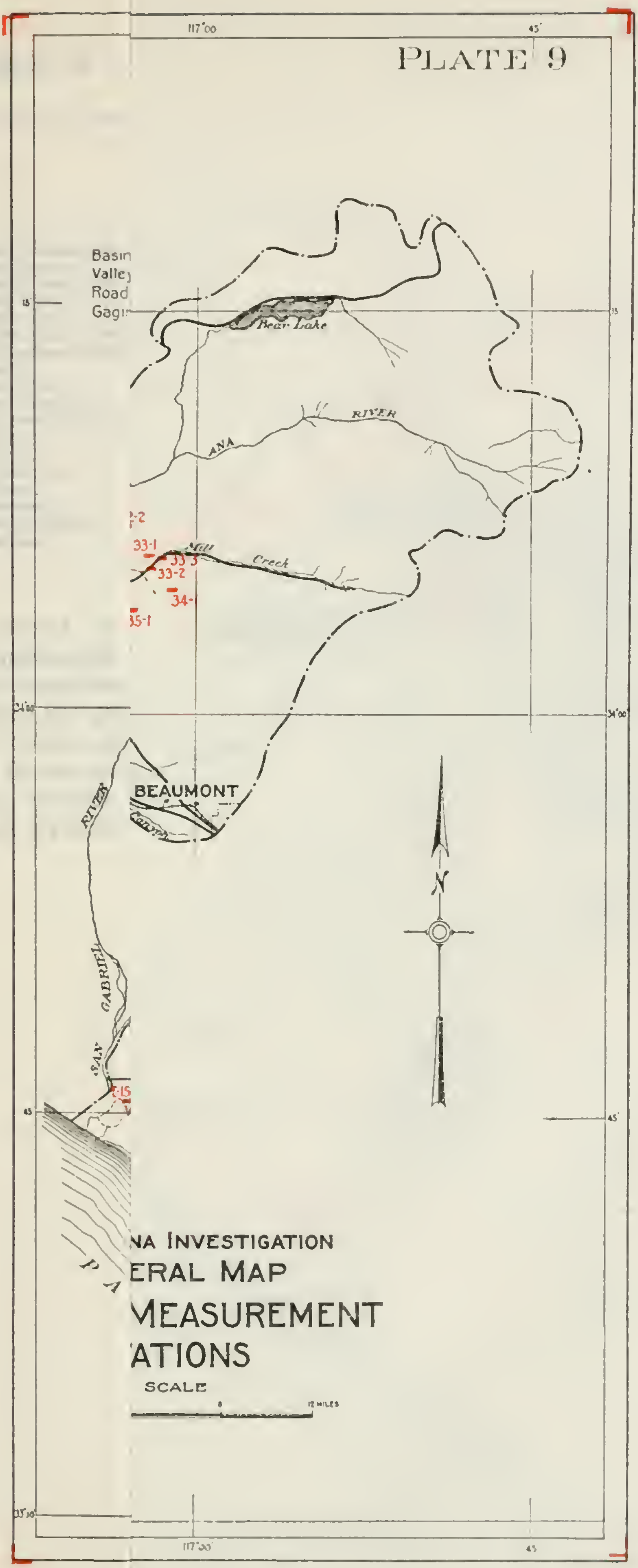

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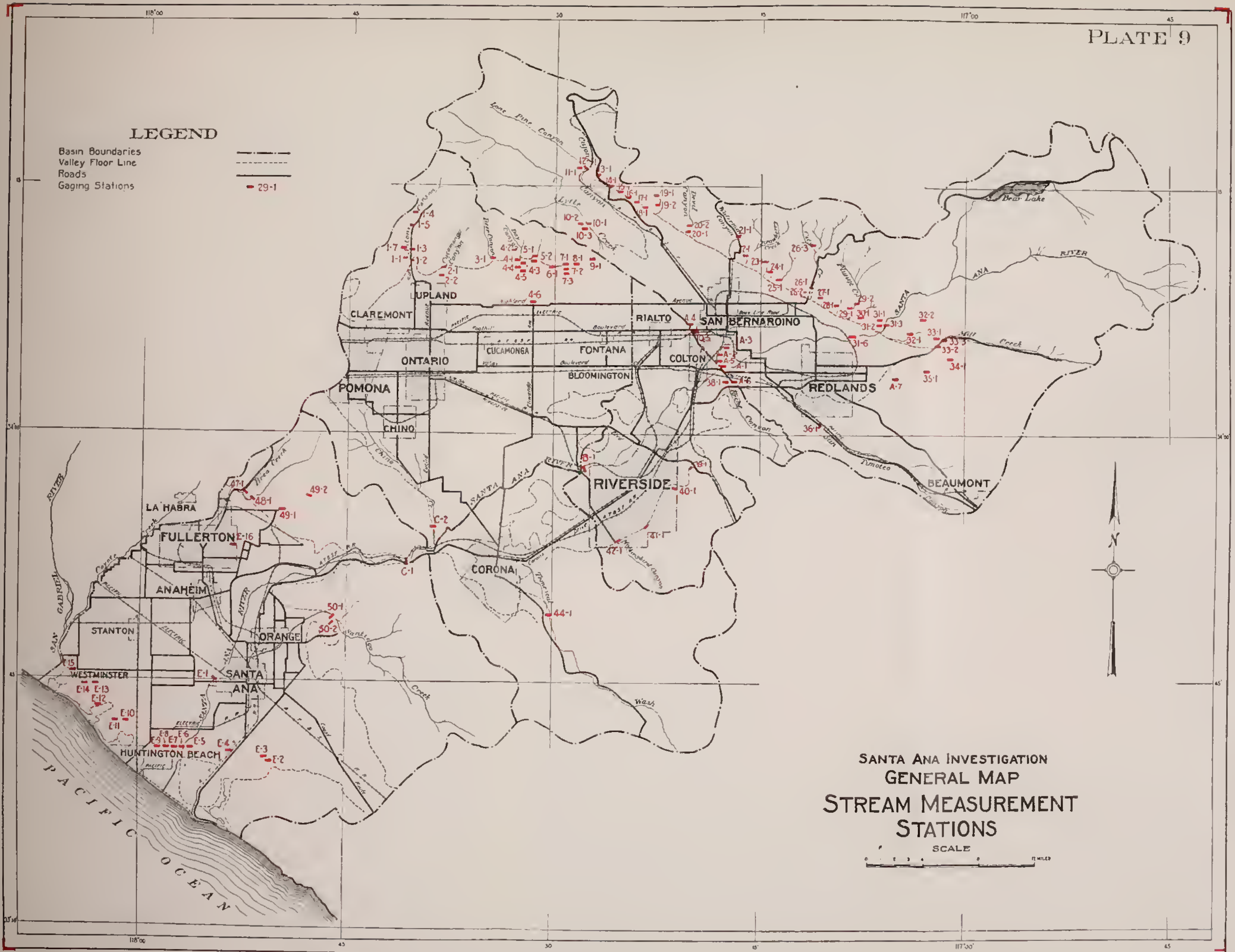

PLATE 9
LEGEND
Basin Boundaries
Valley Floor Line
Roads
Gaging Stations
29-1
SANTA ANA INVESTIGATION
GENERAL MAP
STREAM MEASUREMENT
STATIONS
SCALE
UPLAND
CLAREMONT
ONTARIO
CUCAMONGA
FONTANA
RIALTO
SAN BERNARDINO
COLTON
BLOOMINGTON
POMONA
REDLANDS
CHINO
RIVERSIDE
BEAUMONT
LA HABRA
FULLERTON
CORONA
ANAHEIM
STANTON
ORANGE
SANTA ANA
WESTMINSTER
HUNTINGTON BEACH
PACIFIC OCEAN
Bear Lake
SANTA ANA RIVER
Mill Creek
Lytle Creek

63685

TABLE 30. STORM FLOW BY ALTITUDE AND STREAM GRADIENT FOR SEASON 1926-1927

Stream	Highest altitude	Grade feet per mile	Storm flow per square mile, acre-feet
Small drainage, high altitude:			
San Antonio	11,000	1,300	815
Large drainage, high altitude:			
Mill Creek	11,500	790	504
Lytle Creek	11,000	500	352
Santa Ana at Mentone	11,500	290	428
Flat Grade and gravel storage in upper course:			
Cajon	7,000	1,000	91
Lone Pine	8,000	480	12
San Timoteo	8,500	320	70
High, steep and short:			
City	6,300	760	533
Devil	5,200	910	482
Waterman	5,000	880	414
Plunge	6,300	710	382
Strawberry	6,100	920	332
Coast Mountains:			
Santiago	5,700	310	335

Based on this Table 30, values for storm flow were assigned to unmeasured streams, varying from 900 acre-feet per square mile when the gradient is 1400 feet per mile, to 400 acre-feet per square mile when the gradient is 700 feet per mile. Table 31 combines the known perennial annual flow in acre-feet per year observed either in 1926-27 or in the succeeding year and the known or estimated storm flow. The last column of Table 31 is the final run-off per square mile of mountain streams for use in later tables.

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Devil	5,200	910	482
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TABLE 31. OBSERVED AND ESTIMATED RUN-OFF, 1926-1927

	Drainage area, square miles	In acre-feet per square mile				
		Perennial flow			Storm-flow	Total Run-off
		Fall, 1926	Spring, 1927	Observed 1927-28		
San Antonio U. S. G. S.	17.4	420	480		815	1,275
San Antonio, remainder to Power House No. 1	7.6			0	400	400
Evey	1.4			195	400	595
Cucamonga	10.3			300	900	1,200
Deer	3.5			216	900	1,116
Day	4.9			220	850	1,070
East Etiwanda	2.9			180	750	930
Ingvaldsen	1.1			60	750	810
San Sevaine	1.8			60	700	760
Hawker	.5			24	500	524
Howard	.7			24	500	524
Lytle U. S. G. S.	39.4	396	468		416	860
Lone Pine U. S. G. S.	16.7			8	12	20
Cajon U. S. G. S.	41.9			31	92	123
Calwell	1.7			5	400	405
Medlin	.5			24	400	424
Kimbark	1.2			24	400	424
East Kimbark	.9			6	400	406
Unnamed	.2			0	400	400
Ames	1.0			120	400	520
Cable	2.7			148	500	648
Devil	6.3	24	48		482	522
Waterman	4.5	24	48		414	453
Strawberry	9.2			72	332	404
Bishops	.7			0	500	500
Little Sand	1.2			0	500	500
Sand	3.1			0	500	500
City	19.8	72	84		533	613
Reservoir	1.1			0	500	500
East Highland	1.2			72	500	572
Plunge	16.8			18	382	400
Oak	2.2			36	400	436
Santa Ana, Mentone exclusive of Bear Valley	147.6	108	240		428	624
Morton	2.2			36	400	436
Mill	43.6	300	432		504	892
Spoor	1.2			24	600	624
Ward	.2			0	600	600
San Timoteo	119.6			0	70	70
Reche	11.6			0	300	300
Box Springs	3.6			0	390	390
Sycamore	9.5			0	350	350
Unnamed	7.3			0	300	300
Mocking Bird	10.5			0	300	300
Temescal	115.8			0	300	300
Santiago	85.6	43	60		339	373
Carbon	17.8			0	300	300
Brea	19.8			0	300	300

The run-off of unmeasured foothills and isolated hills is an estimate. This estimate considers the elevations, comparison with adjacent known areas, the steepness of slopes and character of soil. The following table shows the run-off per square mile arbitrarily assigned to such areas for 1926-27:

TABLE 32. RUN-OFF, FOOTHILLS AND ISOLATED HILLS

Index numbers refer to Map No. 4, in pocket

Run-off per square mile used in 1926-1927 restoration.

Upper Basin		Jurupa Basin		Cucamonga Basin		Temescal Basin		Lower Basin	
Drainage index No.	Run-off, acre-feet per square mile	Drainage index No.	Run-off, acre-feet per square mile	Drainage index No.	Run-off, acre-feet per square mile	Drainage index No.	Run-off, acre-feet per square mile	Drainage index No.	Run-off, acre-feet per square mile
Foothills		Foothills		Foothills		Foothills		Foothills	
35-A	400	38-A	300	1-A	300	44-A	250	49-A	200
13-A	300	39-A	250	2-A	300			48-A	200
21-A	300	40-A	250	3-A	300			47-A	150
22-A	300	42-A	250	4-A	300			51-A	150
26-A	300			5-A	250			53-A	200
28-A	300			6-A	250			53-B	200
29-A	300			7-A	250			52-A	200
30-A	300			8-A	250			52-B	200
31-A	300			9-A	250			50-A	200
32-A	300			46-A	200				
33-A	300			46-C	200				
34-A	300								
36-A	300								
10-A	250								
12-A	150								
Isolated Hills		Isolated Hills		Isolated Hills		Isolated Hills		Isolated Hills	
37-A	250	43-A	200	46-B	200	45-A	250		
37-B	250	43-B	200	46-D	200	45-B	250		
37-C	250	43-C	200	46-E	200	45-C	250		
		43-D	200						
		43-E	200						
		43-F	200						
		43-G	200						
		43-H	200						
		43-J	200						

After study of the storm variation of small areas where data existed, the run-off per square mile upon the valley floor proper for 1926-27 was taken as follows: Within Upper Basin 50 acre-feet per square mile, within Jurupa Basin 80, within Cucamonga Basin 40, within Temescal Basin 10, and within Lower Basin 40.

The final element of the total supply is penetration of rainfall into the gravels of the valley floor. The values for penetration have been fully discussed in section 4, page 152, and are so used in the tabulation.

The values of run-off in acre-feet per square mile given in Tables 31 and 32 and in above paragraphs have been multiplied by the square miles of drainage area, and the whole assembled in Table 33. This table is a complete accounting of all sources of supply; namely, run-off, underflow, rainfall penetration on the valley floor and imported waters.

In this table the supply is given, followed by the escape from each basin. Escape includes exported waters, surface discharge and underflow.

TABLE 33. OBSERVED AND ESTIMATED SUPPLY TO AND ESCAPE FROM THE VARIOUS BASINS, IN 1926-27 AND 1927-28

Notation

* Indicates all streams gaged throughout the season. Under this also are placed streams known to have been dry in October and November, 1927, gagings being begun in December.

A Indicates an arbitrary continuous flow of two second-feet for last item in Upper Basin Supply.

B The run-off of ditches E-5, E-6, E-7 and E-8 in the Lower Basin for the year 1926-1927, include flood waters from levee break on the Santa Ana River.

Drainage index numbers are shown on Map No. 4, in pocket; service area index numbers are shown on Map 7, in pocket; gage station index numbers are shown on Plate No. 9, facing Page 184.

TABLE 33. SUPPLY TO UPPER BASIN

Drainage index No.	Gage station index No.	Creek, canyon or area	Area, square miles	1926-1927 supply, acre-feet	1927-1928 supply, acre-feet
10		Lytle Creek	39.4		
	10–1	Channel, U. S. G. S.		*7,090	*1
	10–3	Fontana Pipe Line, U. S. G. S.		*26,800	*16,800
	10–4	Underflow		*2,200	*2,200
				36,090	19,001
10-A		Foothills adjacent to Lytle Creek	3.2	800	0
11	11–1	Lone Pine Creek, U. S. G. S.	16.7	*329	*119
12	12–1	Cajon Creek, U. S. G. S.	41.9	*5,110	*1,680
12-A		Foothills adjacent to Cajon Creek	4.8	720	0
13		Calwell Creek	1.7	688	*58
14	14–1	Medlin Canyon	.5	212	*51
15	15–1	Kimbark Canyon	1.2	508	*202
16	16–1	East Kimbark Canyon	.9	370	*147
17	17–1	Unnamed Canyon	.2	80	*72
18	18–1	Ames Canyon	1.0	520	*144
19	19–1	Cable Canyon	2.7		
	19–1	Channel		1,370	*325
	19–2	Meyer Co. Pipe		400	400
				1,770	725
19-A		Foothills adjacent from Calwell Creek to Cable Canyon	6.4	1,920	10
20		Devil's Canyon	6.3		
	20–1	Channel, U. S. G. S.		*2,070	*165
	20–2	City of San Bernardino		*1,210	665
				3,280	830
21	21–1	Waterman Canyon, U. S. G. S.	4.5	*2,040	*635
21-A		Foothills between Devil's and Strawberry Canyons	4.8	1,440	10
22	22–1	Strawberry, U. S. G. S.	9.2	*3,720	*1,320
23	23–1	Bishop's Canyon	.7	350	*19
24	24–1	Little Sand Creek	1.2	600	*34
25	25–1	Sand Creek	3.1	1,550	*68
22-A		Foothills. between Strawberry and Sand Creek	2.5	750	5
26		City Creek	19.8		
	26–1	Channel, U. S. G. S.		*10,400	*1,870
		City Creek Water Company's Canal, U.S.G.S.		*1,697	*1,080
				12,097	*2,950
26-A		Foothills, between Sand Creek and Reservoir Canyon	2.9	870	5
27	27–1	Reservoir Canyon	1.1	550	*10
28	28–1	East Highland Storm Drain	1.2	686	*441
28-A		Foothills, between Reservoir Canyon and Plunge Creek	1.2	360	0
29		Plunge Creek	16.8		
	29–1	Channel, U. S. G. S. Less Alder Creek water		*6,205	*683
	29–2	East Orange Co.		508	235
				6,713	918
29-A		Foothills, between Plunge Creek and Oak Canyon	.4	120	0
30	30–1	Oak Canyon	2.2	960	*164
30-A		Foothills, between Oak Canyon and Santa Ana River	1.0	300	0
31		Santa Ana River near Mentone	189.3		
	31–1	Channel, U. S. G. S.		*51,900	*1,750
	31–2	S. C. E. Co., U. S. G. S.		*45,000	*29,800
	31–3	Greenspot, U. S. G. S.		*3,470	*4,230
	31–4	Alder Creek exported		*215	215
	31–5	Underflow		3,500	3,500
				104,085	*39,495

TABLE 33. SUPPLY TO UPPER BASIN—Continued

Drainage index No.	Gage station index No.	Creek, canyon or area	Area, square miles	1926-1927 supply, acre-feet	1927-1928 supply, acre-feet
31-A		Foothills, between Santa Ana River and Morton Canyon	1.2	360	0
32	32-1	Morton Canyon	2.2	960	*330
32-A		Foothills, adjacent to Morton Canyon	2.3	690	0
33		Mill Creek:	43.6		
	33-1	Channel, U. S. G. S.		*17,500	*137
	33-2	Power Canals, U. S. G. S.		*17,600	*13,640
				*35,100	*13,777
34-A	34-1	Spoor Canyon	1.2	748	20
33-A		Foothills, adjacent to Mill Creek	3.3	990	0
34-A		Foothills, adjacent to and west of Spoor Canyon	1.0	300	0
35	35-1	Ward Canyon	.2	120	0
35-A		Crafton Hills, east and west of Ward Canyon	9.9	3,960	5
36	36-1	San Timoteo Creek	119.6		
		Channel		*8,320	*316
		Underflow, Drainage Basin		8,000	8,000
				16,300	8,316
36-A		Hills west of San Timoteo Creek	15.7	4,710	10
37-A		Isolated hills, south of Devil's Canyon	.2	50	0
37-B		Isolated hills, south of Devil's Canyon	.1	25	0
37-C		Isolated hills, south of Devil's Canyon	1.3	325	0
37-D		Isolated hills, south of Devil's Canyon	.2	50	0
37		Valley Floor	124.1		
		Run-off		7,400	0
		Rainfall penetration		50,700	10,700
		Springs		A1,450	A1,450
		Total	714.9	313,800	103,696
		Correction for estimated storage and evaporation in Bear Valley Reservoir		12,000	−10,000
		Total supply to Upper Basin		325,800	93,696

TABLE 33. ESCAPE FROM UPPER BASIN

Gage station index No.	Service area index No.	Stream or diversion	1926–1927 quantity, acre-feet	1927–1928 quantity, acre-feet
		Exported to Cucamonga Basin:		
	21	Fontana Union System via Fontana Canal—		
10-9		(a) Surface diversion	*13,300	*14,000
		(b) Pumping	*3,080	3,500
			16,380	17,500
		Exported to Jurupa Basin:		
	11	Lytle Creek Water & Improvement Co. and City of Rialto—		
		(a) Surface diversion via Fontana Canal	*2,400	*2,400
		(b) Pumping	5,120	5,290
	12	Mutual Land and Water Co., pumping	590	700
	13	Terrace Water Co., pumping	*690	800
	14	Citizens' Land and Water Co., pumping	10,000	10,000
	15	City of Colton, pumping	*1,640	1,800
	16	Riverside Highland Water Co.—		
		(a) Pumping, Lytle Creek	*1,370	1,400
		(b) Wells, Santa Ana River (including water in transit to Corona	*3,050	3,100
A-2	21	Meek and Daley Canal, delivery to West Riverside Canal	*6,600	*6,710
A-5	19, 17, 18	Riverside Water Co. Canal, City of Riverside, Gage Canal	57,300	57,000
			88,760	89,200
		Exported to Moreno Valley:		
		Moreno Pipe Line—		
		(a) Surface diversion	700	700
		(b) Pumping	2,900	2,900
			3,600	3,600
		Run-off to Jurupa Basin:		
A-4		Lytle Creek West Channel, occasional floods	300	0
A-1		Santa Ana River at Colton	66,800	*7,550
			67,100	7,550
		Underflow to Jurupa Basin	20,000	20,000
		Total escape from Upper Basin	195,810	137,850

TABLE 33. SUPPLY TO JURUPA BASIN

Drainage index No.	Gage station index No.	Creek, canyon or area	Area, square miles	1926-1927 supply, acre-feet	1927-1928 supply, acre-feet
		Run-off from Upper Basin:			
		Santa Ana at Colton		66,800	*7,550
		West Channel Lytle Creek		300	0
		Underflow from Upper Basin		20,000	20,000
		Imported waters		88,760	89 200
				175,860	116,750
38	38-1	Reche Canyon	11.6	3,480	5
38-A		Foothills, north of Reche Canyon	.4	120	0
39	39-1	Box Springs Canyon	3.6	1,000	*4
40	40-1	Sycamore Canyon	9.5	2,850	*4
41	41-1	Unnamed Canyon	7.3	2,190	*8
42	42-1	Mocking Bird Canyon	10.5	3,150	*32
40-A		Foothills, between Sycamore Canyon and unnamed canyon	11.3	2,580	30
39-A		Foothills, between Reche Canyon and Box Springs Canyon	7.7	1,925	20
42-A		Foothill, between Unnamed Canyon and Mocking Bird Canyon	3.7	925	10
43-A		Isolated hills, west of Colton	.3	60	0
43-B		Isolated hills, south of Colton	1.3	260	0
43-C		Isolated hills, north of Rubidoux Bridge	1.8	360	0
43-D		Isolated hills, north of Rubidoux Bridge	1.1	220	0
43-E		Isolated hills, west of Riverside	1.2	240	0
43-F		Isolated hills, west of Riverside	.4	80	0
43-G		Isolated hills, south of Riverside	.6	120	0
43-H		Isolated hills, east of Arlington	.2	40	0
43-I		Isolated hills, east of Pedley	.7	140	0
43-J		Isolated hills, west of Arlington	.4	80	0
43-K		Isolated hills, west of Arlington	.3	60	0
43		Valley Floor	99.1		
		Run-off		8,000	0
		Rainfall penetration		22,000	4,100
		Springs		1,400	1,400
		Total supply to Jurupa Basin	172.6	227,220	122,363

TABLE 33. ESCAPE FROM JURUPA BASIN

Gage station index No.	Service area index No.	Stream or diversion	1926–1927 quantity, acre-feet	1927–1928 quantity, acre-feet
		Exported to Cucamonga Basin:		
	20	West Riverside Canal, Pedley-Wineville Region	7,700	7,700
		Exported to Temescal Basin:		
	20	West Riverside Canal, La Sierra Heights Region	*1,150	1,000
	18	Gage Canal—		
		(a) Region west of Arlington	2,000	2,000
		(b) Corona Region (T. W. Co.)	*3,570	3,600
	19	Riverside Water Co. Canal, Region West of Arlington	4,000	4,000
			10,720	10,600
		Run-off to Cucamonga Basin:		
B-1		In transit to Lower Basin Santa Ana River at Pedley Bridge	105,000	*47,400
		Underflow to Cucamonga Basin, in transit to Lower Basin	300	300
		Total Jurupa Basin escape	123,720	66,000

TABLE 33. SUPPLY TO CUCAMONGA BASIN

Drainage index No.	Gage station index No.	Creek, canyon or area	Area, square miles	1926-1927 supply, acre-feet	1927-1928 supply, acre-feet
		Run-off and underflow, in transit to Lower Basin, escaping from Jurupa Basin		105,300	47,700
		Imported from Upper Basin		16,380	17,500
		Imported from Jurupa Basin		7,700	7,700
1		San Antonio Canyon	25.0		
	1-3	Channel at steel bridge		15,200	*90
	1-7	Ontario Power House No. 1		*11,423	*8,015
	1-10	Underflow		1,000	1,000
				27,623	9,105
1-B		Evey Canyon	1.4	835	250
1-A		Foothills, adjacent to Evey Canyon	.7	210	0
1-A		Foothills, adjacent to San Antonio Canyon	1.6	480	0
2		Cucamonga Canyon	10.3		
	2-1	Channel		12,350	*2,600
		Underflow		*72	*72
				12,422	2,672
2-A		Foothills, adjacent to Cucamonga Canyon	2.1	630	10
3		Deer Canyon	3.5		
	3-1	Channel		3,000	*0
	3-2	Hermosa Water Co.		*900	*838
				3,900	838
3-A		Foothills, adjacent to Deer Canyon	2.8	840	10
4		Day Canyon	4.9		
	4-1	Channel		5,250	*1,280
	4-3	Etiwanda spreading (above)		400	*320
	4-7	Underflow		1,000	1,000
				6,650	2,600
4-A		Foothills, between Deer Canyon and Day Canyon	2.2	660	10
5	5-1	East Etiwanda Creek	2.9	2,900	*848
5-A		Foothills, between Day Canyon and East Etiwanda Creek	.4	100	0
6	6-1	Ingvaldsen Canyon	1.1	890	*158
6-A		Foothills, between East Etiwanda Creek and Ingvaldsen Canyon	1.1	275	0
7	7-1	San Sevaine Canyon	1.8	1,370	*524
7-A		Foothills, between Ingvaldsen Canyon and Hawker Canyon	.8	200	0
8	8-1	Hawker Canyon	.5	262	*49
8-A		Foothills, between Hawker Canyon and Howard Canyon	.8	200	0
9	9-1	Howard Canyon	.7	365	*144
9-A		Foothills, adjacent to Howard Canyon	.1	25	0
46-A		Foothills, west of Chino Creek	18.3	3,660	0
46-C		Isolated Jurupa hills	4.4	880	0
46-D		Isolated Jurupa hills	2.0	400	0
46-E		Isolated Jurupa hills	.5	100	0
46-B		Foothills, west of Chino Creek	12.8	2,560	0
46		Valley Floor	268.0		
		Run-off		10,300	0
		Rainfall penetration		126,700	41,700
		Springs		0	0
		Total supply to Cucamonga Basin	371.6	334,817	131,818

NOTE—These totals include as supply the escape from Jurupa Basin, in reality in transit through Cucamonga Basin to Lower Basin. This escape amounted to 105,300 acre-feet in 1926–27 and to 47,700 acre-feet in 1927–28.

TABLE 33. ESCAPE FROM CUCAMONGA BASIN

Gage station index No.	Service area index No.	Stream or diversion	1926–1927 quantity, acre-feet	1927–1928 quantity, acre-feet
----------	----------	Escape from Jurupa Basin, in transit through Cucamonga Basin to Lower Basin	105,300	*47,700
		Run-off to Lower Basin:		
C-2	----------	(a) Chino Creek Bridge near Chino	13,000	*6,130
----------	----------	(b) Springs and rising water flowing to Lower Basin as determined from comparison of quantities passing Pedley Bridge and U. S. G. S. Station at Prado	31,700	28,770
		Total Cucamonga Basin escape	150,000	82,600

NOTE.—These totals include the escape from Jurupa Basin considered to be in transit through Cucamonga Basin to Lower Basin.

NOTE.—The escape from Cucamonga Basin plus the escape from Temescal Basin equals the U. S. G. S. discharge at Prado plus underflow at Prado.

TABLE 33. SUPPLY TO TEMESCAL BASIN

Drainage index No.	Gage station index No.	Creek, canyon or area	Area, square miles	1926-1927 supply, acre-feet	1927-1928 supply, acre-feet
----------	----------	Imported from Jurupa Basin	----------	10,720	10,600
----------	----------	Imported from San Jacinto River	----------	*1,294	*3,027
44	44-1	Temescal Creek	115.8	34,800	*927
45-A	----------	Isolated hills, north of Corona	8.2	1,640	50
45-B	----------	Isolated hills, north of Corona	.3	60	0
45-C	----------	Isolated hills, north of Corona	.2	40	0
45-A	----------	Foothills, adjacent to Temescal Creek	30.7	7,675	100
45	----------	Valley floor	55.9	----------	----------
----------	----------	Run-off	----------	500	0
----------	----------	Rainfall penetration	----------	9,000	4,600
----------	----------	Springs	----------	0	0
		Total supply to Temescal Basin	211.1	65,729	19,304

TABLE 33. ESCAPE FROM TEMESCAL BASIN

Gage station index No.	Service area index No.	Stream or diversion	1926–1927 quantity, acre-feet	1927–1928 quantity, acre-feet
		Run-off to Lower Basin:		
33-1	----------	(a) Temescal Creek, occasional floods	12,000	0
----------	----------	(b) Estimated underflow to Lower Basin	2,000	2,000
		Total Temescal Basin escape	14,000	2,000

TABLE 33. SUPPLY TO LOWER BASIN

Drainage index No.	Gage station index No.	Stream, or area	Area, square miles	1926-1927 supply, acre-feet	1927-1928 supply, acre-feet
		Run-off at Prado		*159,000	*79,600
		Underflow at Prado		5,000	5,000
52-A		Hills North of River	17.6	3,500	0
52-B		Hills South of River	18.1	53,600	0
50		Santiago Creek	85.6		
	50-1	Channel, U. S. G. S.		*28,700	*800
	50-2	Serrano and Carpenter Canal, U. S. G. S.		*3,190	*2,690
				31,890	*3,490
50-A		Hills adjacent to Santiago Creek	8.8	1,750	0
49	49-1	Carbon Canyon	12.6	3,540	2
48	48-1	Brea Canyon, South Fork	12.0	2,400	109
47	47-1	Brea Canyon, North Fork	7.8	1,560	42
49-A		Hills, Yorba Linda Region	4.6	900	0
48-A		Hills, Near Olinda	6.7	1,350	0
47-A		Hills, adjacent to Brea Canyon	2.6	400	0
51-A		Hills, North of Fullerton	9.4	1,400	0
		Run-off:			
53-A		Hills, Tustin to El Toro	37.6	7,500	0
53-B		Laguna Hills	18.6	3,700	0
51		Valley floor	305.6		
		Run-off		13,690	0
		Rainfall penetration		79,200	76,900
		Total supply to Lower Basin	552.8	320,380	165,143

TABLE 33. ESCAPE TO OCEAN FROM LOWER BASIN

Gage station index No.	Service area index No.	Stream or area	1926-1927 quantity, acre-feet	1927-1928 quantity, acre-feet
		Run-off to Ocean:		
E-1		Santa Ana River at Santa Ana, U. S. G. S.	*67,000	*1,530
E-4		Drainage Ditch	1,000	*970
E-3		Drainage Ditch	2,000	*132
E-2		Drainage Ditch	2,300	*1,035
E-15		Drainage Ditch	200	0
E-14		Drainage Ditch	200	0
E-13		Drainage Ditch	200	0
E-12		Drainage Ditch	280	*108
E-11		Drainage Ditch	2,000	*1,270
E-10		Drainage Ditch	2,000	*979
E-9		Drainage Ditch	1,530	*836
E-8		Drainage Ditch	B880	*176
E-7		Drainage Ditch	B2,040	*36
E-6		Drainage Ditch	B4,260	*545
E-5		Drainage Ditch	B1,850	*871
		Metropolitan Sewerage System out-fall	3,600	3,600
		Run-off to Ocean via San Gabriel River:		
		Brea Creek near Northam	5,800	0
		Foothill Drain from Fullerton	300	0
		Old Anaheim Channel near Alamitos	6,300	0
		Underflow to Ocean	8,000	8,000
		Total Lower Basin escape	111,740	20,088

LONG PERIOD RUN-OFF

Mean or Average Run-off. To ascertain the mean run-off a sufficient period of years must be taken to cover cycles of wet and dry years. Where actual measurements do not exist, it is necessary to estimate for unknown years. The practice of comparing the known records of run-off with corresponding known records of rainfall and assuming that run-off in the unknown period varied similarly with the rainfall of that period, has not been used in this study. A more accurate result is obtained by comparing the variations of streams with a short period of measurement, with one of a long period of measurement and estimating the record on this relationship. This method has been used in this study. In 1896–97 the U. S. Geological Survey began making measurements. Measurements on the adjoining watershed of the San Jacinto began in 1894. The year 1894–95 is taken as the initial year for long period run-off computations. This constitutes a period of 34 years. It bridges the "critical period" of greatest known sustained deficiency, 1895 to 1902. As afterward shown the mean rainfall for this 34-year period does not materially differ from the mean rainfall for 50 years. The use of the 34-year period permits the estimates to be entirely from stream gagings, and avoids resort to estimates based on rainfall.

The Streams Measured. For the first seven years of this 34-year period, the U. S. Geological Survey maintained only the gaging station on the main Santa Ana River at Mentone with a drainage area of 189 square miles. That is for the first seven years 9 per cent of the total 2050 square miles of watershed was under measurement. In the next 11 years one more stream, the San Antonio Creek, was added, making 10 per cent of watershed under measurement, although some partial records existed elsewhere. In 1912–13 the list was increased by Waterman Canyon. In the following year Lytle, Cajon, Lone Pine and Devil's canyons were added, so that in the next period of seven years 16 per cent of the watershed was under measurement. From 1919–20 to date, a period of nine years, the master station in the lower Santa Ana Canyon has been installed, and another registering the waste of the river into the ocean. At the present time the U. S. Geological Survey maintains 15 gaging stations within the watershed. In 1927–28 61 additional stations were installed by this investigation, making possible a close accounting of all waters. The total number of gaging stations operating in 1928 is 77.

Index of Run-off. Index of run-off is defined as the relationship between the run-off any one year and the mean run-off expressed in percentage.

Santa Ana River at Mentone. A complete record exists at the U. S. Geological Survey station on the Santa Ana River at Mentone for the years 1896–98 and 1902 to date. These records include the flow in various canals diverting out of the Santa Ana River during this period.

During this otherwise complete record there are several short missing periods. The first occurred during January, 1910, and the other during January and February, 1916. Both of these periods have been estimated based on a comparison with San Gabriel River.

In order to lengthen and complete the record the run-off was estimated for the years 1894–95 and 1895–96, and also for the period from 1898 to 1902. These estimates have been based on the index of run-off for the drainage area above Lake Hemet, which is very similar to that of the Santa Ana River.

In order to obtain the natural run-off as it would have flowed without the Bear Valley Reservoir the record is corrected for the influence of this reservoir. The evaporation in the lake is added, and the storage restored to the period when it was received. These deductions or additions are based on the gage records of storage of Bear Valley Reservoir.

The mean run-off of Santa Ana River at Mentone, for 34 years thus partially estimated, and so corrected for Bear Valley Reservoir storage, is 75,900 acre-feet. During this period the maximum year of run-off was 1915–16 with an index of run-off of 370. The minimum occurred in 1898–99 with an index of run-off of 21.

The year 1926–27 with a run-off of 112,000 acre-feet has an index of run-off of 147. While the index of run-off is not large, yet the peak discharge was the second largest during the period of record. The index of run-off for 1927–28 has been estimated at 34, giving a run-off of 25,800 acre-feet.

Relationship Between 34 and 50-Year Periods. In order to determine the relationship of the past 34 years of actual record as compared with the 50-year period as published by the state in Water Resources Investigation (1924) Bulletin 5, the following study has been made.

To the table of index of seasonal wetness (1871–1921) has been added the last seven years of rainfall using the same system as employed by the state.

The table of index of run-off (1871–1921) has also been carried up to date in order to make the comparisons. A correction has been made to the state's record for 1915–16 due to the probable underestimate of the storm run-off for that year on the Santa Ana River at Mentone as given in Bulletin 5. The following tabulation shows the comparison between the means for various periods expressed in seasonal index of wetness and index of run-off.

Period	Length of period	Index of wetness	Index of run-off
1871-1921	50 year	100	A101
1871-1928	57 year	100	99
1878-1928	50 year	100	99
1894-1928	34 year	99	97

A Due to correction made to records for 1915-16. The mean has been increased 1 per cent above that published in Bulletin No. 5.

Other Measured Streams. Besides the record on the Santa Ana River at Mentone, there are three other records of considerable length. The most complete record of these three is that of the San Antonio Creek near Claremont which has been maintained since 1901. During this period there are four years of missing record, namely 1902–03, 1904–05, 1909–10, and 1915–16. The first three years average about 10 per cent below normal, while that of 1915–16 was one of the wettest years on record.

The other long period records are those on Mill Creek near Craftonville and Lytle Creek near Fontana. Both of these records are very incomplete, Mill Creek having but 14 years of complete record and Lytle Creek 13 years.

The remaining measured streams of the watershed have but eight to 10 years of record.

Method Used in Restoration of 34-Year Record. The guide stream adopted is the Santa Ana River at Mentone. The last 10 years show a substantial agreement with the other streams of the basin with the exception of San Antonio Creek. The discharge of every measured stream was plotted for each year of its record, against each year's discharge of the Santa Ana River at Mentone (corrected for Bear Valley storage) and a curve was platted defining the relationship.

The curves are shown on Plate 10, page 198. These curves were used to reproduce the records for the unmeasured seasons of partially measured streams.

Curve A was used for unmeasured foothill drainage Nos. 36-A, 35-A.

Curve B was used for unmeasured foothill drainage Nos. 13-A, 21-A, 22-A, 26-A, 28-A, 29-A, 30-A, 31-A, 32-A, 33-A, 34-A, 38-A, 1-A, 2-A, 3-A, 4-A.

Curve C was used for unmeasured foothill drainage Nos. 44-A, 45-A, 45-B, 45-C, 5-A, 6-A, 7-A, 8-A, 9-A, 10-A, 37-A, 37-B, 37-C, 37-D, 39-A, 40-A, 42-A.

Curve D was used for unmeasured foothill drainage Nos. 43-A, 43-B, 43-C, 43-D, 43-E, 43-F, 43-G, 43-H, 43-I, 43-J, 43-K, 46-A, 46-C, 46-D, 46-E, 46-B.

Curve E was used for unmeasured foothill drainage No. 12-A.

Curve F was used for unmeasured foothill drainage Nos. 49-A, 48-A, 53-A, 53-B, 52-A, 52-B, 50-A.

Curve G was used for unmeasured foothill drainage Nos. 47-A, 51-A.

Curve H was used for unmeasured mountain areas of Reche, Unnamed and Mockingbird canyons.

Curve I was used for unmeasured mountain areas of Colwell, Medlin, Kimbark, East Kimbark, Unnamed, Oak, Morton, Box Springs, Sycamore, Hawker and Howard canyons.

Curve J was used for unmeasured mountain areas of Ames, Cable, Bishop, Little Sand, Sand and Reservoir canyons.

Curve K was used for unmeasured mountain areas of East Highland Storm Drain, Spoor, Ward and Evey canyons.

Curve L was used for unmeasured mountain areas of Ingvaldsen and San Sevaine canyons.

Curve M was used for unmeasured mountain areas of East Etiwanda Creek.

Curve N was used for unmeasured mountain areas of Day and Deer canyons.

Curve O was used for unmeasured mountain areas of Temescal Creek.

Curve P was used for unmeasured mountain areas of Cucamonga Creek.

Curve Q was used for unmeasured mountain areas of Carbon and Brea canyons.

Curve R was used for unmeasured mountain areas of San Timoteo Creek.

Table 34, page 199, shows the application of this method for the group of streams having records of considerable length. The quantities marked by * are known measured quantities, the others are restored.

Table 35, page 200, shows the estimated "supply originating locally in each basin." The last column is the total water received annually from all sources over the entire watershed. The detail computation of Table 35 consisted in arranging the sources into six groups; the measured streams as shown in Table 34, page 199, the unmeasured streams being those with less than two years of record, unmeasured foothill areas and isolated hills, run-off within the valley floor, rainfall penetration on the valley floor and underflow. The values estimated from Plate 10, page 198, were assigned to each group as applicable. Rainfall penetration and underflow were taken as explained in Section 4, page 152, and Section 7, page 180. The run-off within the valley floor was taken as varying with the rainfall. In general it was estimated to begin at 14 inches of rain, reaching 60 acre-feet per square mile with 23 inches of rain, and 100 acre-feet per square mile with 29 inches of rain.

PLATE 10

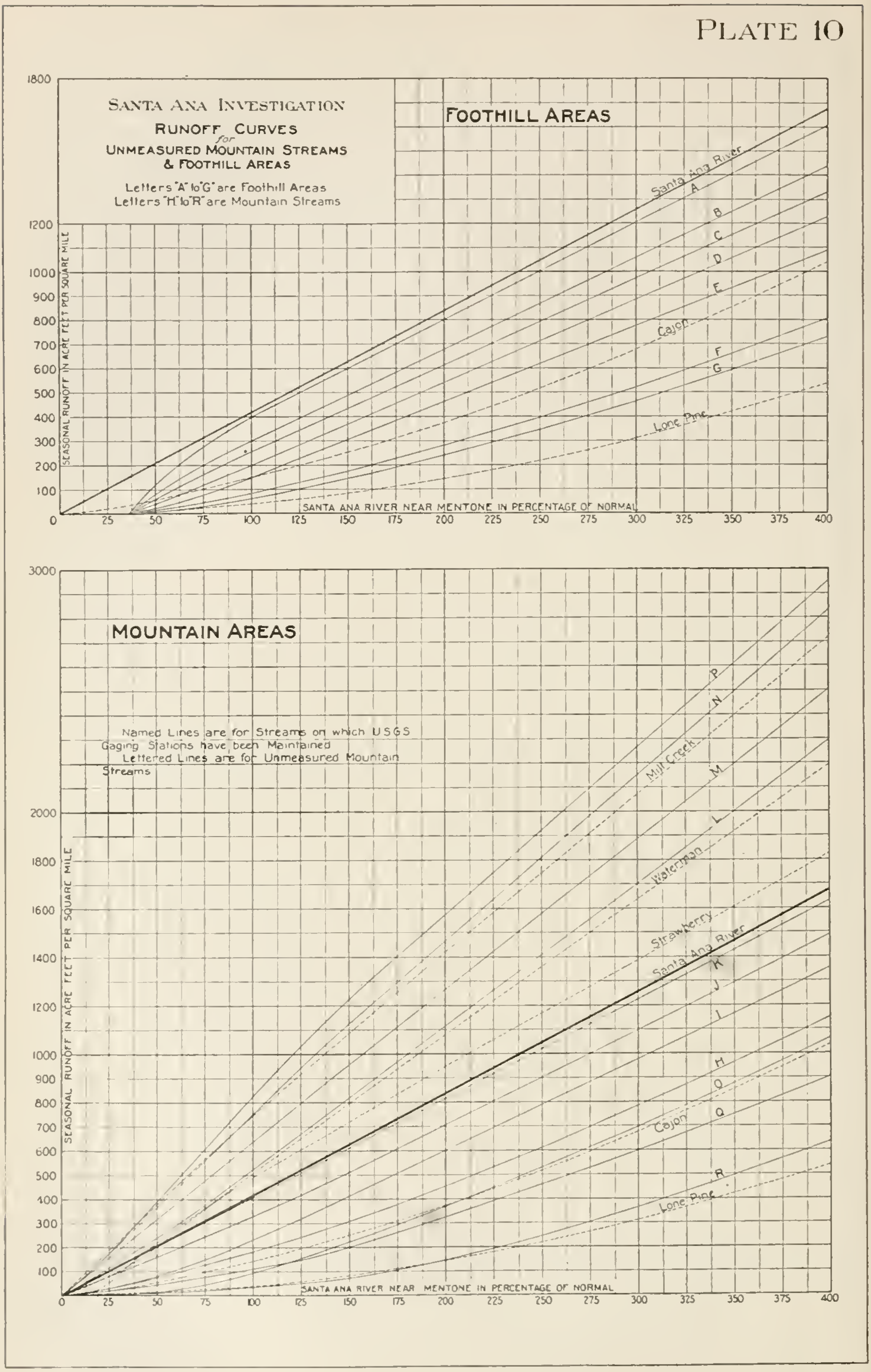

SANTA ANA INVESTIGATION
RUNOFF CURVES for UNMEASURED MOUNTAIN STREAMS & FOOTHILL AREAS
Letters "A" to "G" are Foothill Areas
Letters "H" to "R" are Mountain Streams
FOOTHILL AREAS
Santa Ana River
A
B
C
D
E
Cajon
F
G
Lone Pine
SEASONAL RUNOFF IN ACRE FEET PER SQUARE MILE
SANTA ANA RIVER NEAR MENTONE IN PERCENTAGE OF NORMAL
MOUNTAIN AREAS
Named Lines are for Streams on which U S G S Gaging Stations have been Maintained
Lettered Lines are for Unmeasured Mountain Streams
P
N
Mill Creek
M
L
Waterman
Strawberry
Santa Ana River
K
J
I
H
O
Cajon
Q
R
Lone Pine
SEASONAL RUNOFF IN ACRE FEET PER SQUARE MILE
SANTA ANA RIVER NEAR MENTONE IN PERCENTAGE OF NORMAL

TABLE 34. RECORD OF MEASURED STREAMS AND RESTORATIONS FOR 34 YEAR PERIOD IN ACRE-FEET

Year	Santa Ana river at Mentone (corrected for storage) (A)	Index of run-off	San Antonio creek near Claremont	Lytle creek near Fontana (A)	Cajon creek near Keenbrook	Lone Pine creek near Keenbrook	Devil's Canyon near San Bernardino (A)	Waterman Canyon near Arrowhead Springs	Strawberry creek near Arrowhead Springs	City creek near Highland (A)	Plunge creek near East Highland (A)	Mill creek near Craftonville (A)	Warm creek near Colton (B)	Santa Ana river near Prado (B)	Santiago creek near Villa Park (A)	Santa Ana river at Santa Ana
1894-95	151,000	203	39,500	49,800	16,200	2,480	7,700	4,950	8,800	18,700	14,400	63,000	83,800	285,000	25,200	115,000
1895-96	25,000	33	5,400	11,000	1,600	100	1,100	480	1,150	2,700	800	11,600	40,000	85,000	500	0
1896-97	*65,000	86	15,000	21,000	5,000	520	3,300	1,920	3,750	8,000	5,300	28,300	62,200	127,000	5,500	9,200
1897-98	*28,800	38	6,200	12,000	1,900	140	1,250	580	1,400	3,200	1,200	13,000	44,000	88,000	800	0
1898-99	16,000	21	3,400	7,000	1,000	60	600	220	600	1,600	300	7,200	40,000	87,500	200	0
1899-00	16,500	22	3,800	7,200	1,100	60	700	220	650	1,700	300	7,400	40,000	89,200	200	0
1900-01	47,400	62	10,400	18,000	3,300	290	2,250	1,220	2,600	5,600	3,100	20,600	51,400	92,000	2,500	200
1901-02	23,100	31	*5,050	10,000	1,600	100	1,000	420	1,050	2,500	700	10,800	40,000	80,000	500	0
1902-03	*67,900	90	8,050	25,000	5,300	510	3,400	2,020	3,900	8,400	5,500	29,500	60,400	120,000	5,900	7,800
1903-04	*24,600	32	*6,340	10,200	1,600	100	1,000	440	1,150	2,600	700	11,000	42,000	66,800	590	0
1904-05	*61,360	81	21,500	22,800	4,700	450	3,100	1,780	3,500	7,500	4,800	26,600	58,000	112,000	4,700	3,700
1905-06	*123,100	162	*35,800	40,200	11,800	1,600	6,200	3,880	7,150	15,000	11,200	37,500	75,200	203,000	17,500	53,400
1906-07	*161,600	217	*33,800	51,500	18,000	2,850	8,200	5,320	9,500	20,000	15,500	46,000	85,000	300,000	27,900	126,600
1907-08	*60,100	79	*11,800	32,100	4,500	430	3,000	1,720	3,400	7,400	4,600	26,000	62,000	125,000	4,400	6,800
1908-09	*85,700	113	*28,400	30,200	7,300	810	4,300	2,620	5,000	10,500	7,400	36,290	69,000	160,000	9,100	25,400
1909-10	*86,800	114	24,300	30,400	7,400	850	4,400	2,680	5,100	10,600	7,500	37,000	71,400	173,000	9,600	31,800
1910-11	*101,600	134	*18,100	43,000	9,200	1,150	5,200	3,200	5,900	12,500	9,100	70,600	73,200	187,000	12,900	42,800
1911-12	*43,800	58	*11,300	21,700	3,100	260	2,100	4,510	2,400	5,300	2,900	19,500	53,000	97,000	2,200	0
1912-13	*33,200	44	*7,150	13,600	2,300	160	1,550	*1,390	1,650	3,900	1,600	15,000	40,000	80,000	1,200	0
1913-14	*91,200	124	*25,500	56,000	c20,000	c4,000	*4,980	*6,020	5,500	11,600	8,400	40,000	68,800	155,000	11,200	25,200
1914-15	*138,200	182	*20,200	*31,000	8,400	2,000	6,900	4,420	8,000	16,800	12,800	57,000	76,000	209,000	21,300	61,000
1915-16	280,500	370	26,500	*80,400	36,200	7,360	13,500	9,060	15,600	33,000	26,700	109,600	95,000	456,000	59,000	286,500
1916-17	*71,000	93	*14,900	*23,700	5,600	580	3,600	2,100	4,100	8,600	5,700	30,800	66,200	145,000	6,400	17,200
1917-18	*81,200	111	*17,700	*27,800	9,100	810	4,250	2,580	4,900	10,100	7,200	36,000	71,400	172,000	9,000	31,200
1918-19	*39,700	52	*7,470	*17,800	2,700	210	1,800	1,000	2,050	4,600	2,300	17,800	51,400	102,000	1,600	0
1919-20	*80,500	106	*18,100	*26,500	6,700	750	4,100	2,460	4,650	9,900	6,800	*31,600	66,000	139,000	8,300	17,800
1920-21	*53,700	71	*13,700	*21,100	*3,130	*381	2,700	*1,840	*3,170	6,500	4,000	*23,900	*56,100	*115,400	*4,700	1,900
1921-22	*192,700	251	*53,300	57,600	*22,700	*3,810	9,500	*6,420	*11,000	23,300	18,300	*78,200	*85,400	*305,000	*35,100	134,700
1922-23	*60,600	80	*14,700	*25,000	*4,620	*2,090	3,500	*2,230	*3,680	7,400	4,700	*26,200	*66,150	*110,000	*3,700	*2,360
1923-24	*38,900	51	*7,390	*15,700	*2,880	*768	1,600	*784	*1,600	4,600	2,300	*17,500	*58,200	*105,000	*1,550	*1,720
1924-25	*29,800	39	*5,390	*10,600	*2,100	*368	1,300	*555	*1,430	*3,570	1,300	*12,200	*49,600	*81,000	*635	*471
1925-26	*49,300	65	*15,000	*11,700	*3,450	*298	1,900	*1,160	*2,520	*12,650	5,600	*21,900	*52,700	*112,000	*10,400	*21,600
1926-27	*111,600	147	*22,200	*33,900	*5,110	*329	*3,280	*2,040	*3,720	*12,100	*6,710	*38,400	*51,400	*159,000	*31,900	*67,000
1927-28	*25,800	34	*8,340	*16,800	*1,680	*119	*830	*635	*1,320	*2,950	*918	*13,800	*41,600	*79,600	*3,500	*1,530
Mean	75,900	100	16,600	27,100	7,090	1,080	3,650	2,440	4,170	9,290	6,190	31,500	60,300	118,000	10,000	32,100

* Denotes complete record for the year indicated.
(A) Indicates that diversions above the gaging station have been included
(B) Restorations based on actual flow of the Santa Ana River and canals at Mentone, uncorrected for storage in Bear Valley Reservoir.
(c) Estimated on basis of record from Water Supply Paper 447.

TABLE 35. ESTIMATED SUPPLY ORIGINATING LOCALLY IN EACH BASIN IN ACRE-FEET FOR 34-YEAR PERIOD

Year	Index of run-off	Upper Basin	Jurupa Basin	Cucamonga Basin	Temescal Basin	Lower Basin	Total
1894-95	203	474,000	76,800	205,000	67,100	116,000	939,000
1895-96	33	73,100	3,300	13,200	800	1,600	92,000
1896-97	86	203,000	29,000	79,800	15,400	25,900	353,000
1897-98	38	82,000	3,950	15,500	1,200	2,300	105,000
1898-99	21	51,200	2,700	11,800	350	700	66,800
1899-00	22	52,200	2,700	12,800	450	950	69,000
1900-01	62	157,000	27,600	78,600	7,800	34,600	306,000
1901-02	31	68,900	3,150	12,600	700	1,600	87,000
1902-03	90	215,000	33,900	86,500	16,800	47,400	400,000
1903-04	32	70,800	3,200	13,900	800	1,600	90,300
1904-05	81	217,000	46,800	140,000	20,900	89,900	515,000
1905-06	162	366,000	61,200	169,000	50,600	148,000	795,000
1906-07	217	496,000	91,200	231,000	81,600	222,000	1,122,000
1907-08	79	191,000	20,000	60,600	12,900	14,200	299,000
1908-09	113	262,000	38,400	114,000	26,800	51,600	493,000
1909-10	114	249,000	25,800	76,600	27,200	30,900	409,000
1910-11	134	335,000	39,200	98,200	36,000	37,000	545,000
1911-12	58	134,000	8,100	28,000	5,400	9,050	185,000
1912-13	44	96,400	5,400	18,700	2,750	4,050	127,000
1913-14	124	352,000	59,600	168,000	34,400	94,700	709,000
1914-15	182	405,000	65,700	158,000	72,200	126,000	827,000
1915-16	370	868,000	140,000	298,000	188,000	246,000	1,740,000
1916-17	93	203,000	16,000	44,900	18,300	19,200	301,000
1917-18	111	235,000	20,200	54,000	25,500	25,400	360,000
1918-19	52	115,000	6,700	22,000	4,000	7,150	155,000
1919-20	106	251,000	45,500	126,000	24,000	24,200	474,000
1920-21	71	169,000	25,600	72,400	10,300	12,100	289,000
1921-22	254	619,000	115,000	304,000	125,000	201,000	1,364,000
1922-23	80	177,000	13,900	39,700	13,500	13,600	258,000
1923-24	51	111,000	6,800	20,800	3,900	6,450	149,000
1924-25	39	83,000	4,200	14,700	1,750	2,640	106,000
1925-26	65	184,000	41,900	121,000	14,100	23,600	385,000
1926-27	147	326,000	51,350	205,000	53,700	156,000	782,000
1927-28	34	94,000	5,600	58,900	5,680	80,500	245,000
Mean	100	235,000	33,500	93,300	28,800	55,300	446,000

TABLE 35A. ESTIMATED SUPPLY ORIGINATING LOCALLY, SEGREGATED BY SOURCE OF INFORMATION AND AUTHORITY

The 34-year mean given in Table 35 above is made up of the following, in round numbers:

	Drainage area, square miles	Mean, acre-feet
12 mountain streams, measured for long period by U. S. Geological Survey, expanded as shown in Table 34, (not subject to much personal equation)	490	195,000
35 mountain streams, measured by state for one year, expanded for unknown years by methods stated in text with curves of Plate 10, page 198, (largely an estimate)	372	52,000
62 separate foothill and isolated hill areas, estimated from curves of Plate 10, (an estimate)	335	57,000
5 instances of underflow not included in gaging records, (estimated from underflow formula)		16,000
12 springs, (from various records)		3,000
Total designated as mountain and hill run-off both surface and subsurface	1,197	323,000
Valley floor of the five basins	853	
Local run-off (an estimate)		13,000
Rainfall penetration as calculated in section 4, page 152, (an estimate)		110,000
Total estimated supply of all kinds of the watershed	2,050	446,000

Inputs and Escape, 15-year Period. The preceeding Table 35 shows the estimated supply originating in each basin over a 34-year period. In further detail analysis the past 15-year period only has been used, the period from 1913 to 1928. This period is used because within it the hydraulic data is more complete and the objective is to determine how storage has been functioning subsequent to the years 1915 and 1916 when general recharge occurred.

In the following tabulations the assumption is made that:

The input to each basin is the historical supply originating in each basin either measured or estimated, together with the waters additionally entering the basin by natural channels originating in basins above, together with importations into the basin as of 1928.

The escape from each basin is the historical outflow either measured or estimated, together with exportations as of 1928.

The consumptive use and natural losses are taken as of 1928. This assumption is made because no determination of the consumptive use and natural losses in other years is available. It is obvious that the irrigated acreage was less in 1913 than in 1928 and presumably the consumptive use. On the other hand the natural losses and the waste into the ocean may have been compensatingly larger.

The results shown in the following tables 36 to 42 represent, then, an historic situation, subject to the assumption that importations, exportations and consumptive use were as of 1928. The purpose of Tables 38 to 42 is to show as near as may be, what must have been the maximum storage, largely in gravels, during this period. The maximum storage attained, is estimated from these tables as follows: In Upper Basin 585,400 acre-feet, in Jurupa Basin 115,200 acre-feet, in Cucamonga Basin 345,200 acre-feet, in Temescal Basin 127,000 acre-feet and in Lower Basin 350,700 acre-feet, a total of 1,523,500 acre-feet for the entire watershed.

TABLE 36. ESTIMATED INPUT TO EACH BASIN

In acre-feet

(The quantity of water reaching each basin, being the sum of waters originating locally together with waters originating above yet entering the basin, including importations as of 1928)

Year	Upper	Jurupa	Cucamonga	Temescal	Lower
1913-14	352,000	204,000	273,000	46,000	255,000
1914-15	405,000	241,000	299,000	84,200	340,000
1915-16	868,000	498,000	647,000	200,000	707,000
1916-17	203,000	155,000	144,000	30,300	169,000
1917-18	235,000	173,000	170,000	37,500	202,000
1918-19	115,000	124,000	94,000	16,000	114,000
1919-20	254,000	182,000	222,000	36,000	168,000
1920-21	169,000	143,000	152,000	22,300	133,000
1921-22	619,000	349,000	518,000	137,000	511,000
1922-23	177,000	146,000	136,000	25,500	159,000
1923-24	111,000	126,000	97,000	15,900	116,000
1924-25	83,000	116,000	78,700	13,700	88,600
1925-26	184,000	180,000	214,000	26,100	141,000
1926-27	326,000	227,200	334,800	65,700	320,400
1927-28	94,000	122,400	131,800	19,300	165,100
Mean	279,500	198,900	234,100	51,600	239,300

TABLE 37. ESTIMATED ESCAPE FROM EACH BASIN

In acre-feet

(Escape is the sum of the exportations as of 1928 and the natural outflow from each basin)

Year	Upper	Jurupa	Cucamonga	Temescal	Lower
1913-14	165,000	95,100	146,000	14,000	47,700
1914-15	196,000	131,000	189,000	25,000	85,700
1915-16	379,000	339,000	403,000	58,000	321,000
1916-17	160,000	89,000	141,000	9,000	38,700
1917-18	174,000	106,000	163,000	14,000	53,100
1918-19	138,000	62,100	105,000	2,000	20,500
1919-20	157,000	86,100	132,000	12,000	39,600
1920-21	138,000	69,900	112,400	8,000	22,700
1921-22	255,000	204,000	267,000	43,000	162,900
1922-23	153,000	86,100	138,000	7,000	23,500
1923-24	140,000	69,400	108,000	2,000	22,200
1924-25	133,000	57,600	84,000	2,000	20,700
1925-26	159,000	86,400	113,000	4,000	42,400
1926-27	195,800	124,000	150,000	14,000	111,700
1927-28	138,000	66,000	82,600	2,000	20,100
Mean	178,700	111,400	155,600	14,400	68,800

NOTE.—The waters of the Santa Ana River from where it leaves Jurupa Basin at Pedley Bridge to where it enters Lower Basin at Prado is taken as flowing within Cucamonga Basin.

Tables 38 to 42, pages 202 to 204, are studies to determine the storage (largely in gravels) effective during the last 15 years. These tables are based on Tables 36 and 37. Columns 1 and 2 are the result of subtracting escape (Table 37) from input (Table 36). Columns 1 and 2 show that portion of the water annually retained in the basin or indicates a deficiency. They represent water used consumptively and water stored. Column 3 is the estimated consumptive use. Columns 4 and 5 show the residual storage increase or decrease. Column 6 is the accumulated reservoir and gravel storage.

TABLE 38. ESTIMATED RESERVOIR AND GRAVEL STORAGE—UPPER BASIN

In acre-feet

Year	1	2	3	4	5	6
	Retained annually in basin		Consumptive use and natural losses as of 1928	Resulting storage		Accumulated reservoir and gravel storage
	Gain	Deficiency		Increase	Decrease	
October 1, 1913		Accumulated	storage assumed	to be		0
1913-14	187,000		100,800	86,200		86,200
1914-15	209,000		100,800	108,200		194,400
1915-16	489,000		100,800	388,200		582,600
1916-17	43,000		100,800		57,800	524,800
1917-18	61,000		100,800		39,800	485,000
1918-19		23,000	100,800		123,800	361,200
1919-20	97,000		100,800		3,800	357,400
1920-21	31,000		100,800		69,800	287,600
1921-22	364,000		100,800	263,200		550,800
1922-23	24,000		100,800		76,800	474,000
1923-24		29,000	100,800		129,800	344,200
1924-25		50,000	100,800		150,800	193,400
1925-26	25,000		100,800		75,800	117,600
1926-27	130,200		100,800	29,400		147,000
1927-28		41,000	100,800		144,800	2,200

NOTE.—This table does not include the reservoir or gravel storage in the Yucaipa and Beaumont Valleys.

TABLE 39. ESTIMATED RESERVOIR AND GRAVEL STORAGE—JURUPA BASIN

In acre-feet

Year	1	2	3	4	5	6
	Retained annually in basin		Consumptive use and natural losses as of 1928	Resulting storage		Accumulated reservoir and gravel storage
	Gain	Deficiency		Increase	Decrease	
October 1, 1913		Accumulated	storage	assumed	to be	0
1913-14	109,000		87,500	21,500		21,500
1914-15	110,000		87,500	22,500		44,000
1915-16	159,000		87,500	71,500		115,500
1916-17	66,000		87,500		21,500	94,000
1917-18	67,000		87,500		20,500	73,500
1918-19	61,900		87,500		25,600	47,900
1919-20	95,900		87,500	8,400		56,300
1920-21	73,100		87,500		14,400	41,900
1921-22	145,000		87,500	57,500		99,400
1922-23	59,900		87,500		27,600	71,800
1923-24	56,600		87,500		30,900	40,900
1924-25	58,400		87,500		29,100	11,800
1925-26	93,600		87,500	6,100		17,900
1926-27	103,500		87,500	16,000		33,900
1927-28	56,400		87,500		31,100	2,800

TABLE 40. ESTIMATED RESERVOIR AND GRAVEL STORAGE—CUCAMONGA BASIN

In acre-feet

Year	1	2	3	4	5	6
	Retained annually in Basin		Consumptive use and natural losses as of 1928	Resulting storage		Accumulated reservoir and gravel storage
	Gain	Deficiency		Increase	Decrease	
October 1, 1913		Accumulated	storage as-	summed to be		0
1913-14	127,000		78,500	48,500		48,500
1914-15	110,000		78,500	31,500		80,000
1915-16	244,000		78,500	165,500		245,500
1916-17	3,000		78,500		75,500	178,000
1917-18	7,000		78,500		71,500	98,500
1918-19		11,000	78,500		89,500	9,000
1919-20	90,000		78,500	11,500		20,500
1920-21	39,600		78,500		38,900	−18,400
1921-22	251,000		78,500	172,300		154,100
1922-23		2,000	78,500		80,500	73,600
1923-24		11,000	78,500		89,500	−15,900
1924-25		5,300	78,500		83,800	−99,700
1925-26	101,000		78,500	22,500		−77,200
1926-27	184,800		78,500	106,300		29,100
1927-28	49,200		78,500		29,300	−200

TABLE 41. ESTIMATED RESERVOIR AND GRAVEL STORAGE—TEMESCAL BASIN

In acre-feet

Year	1	2	3	4	5	6
	Retained annually in Basin		Consumptive use and natural losses as of 1928	Resulting storage		Accumulated reservoir and gravel storage
	Gain	Deficiency		Increase	Decrease	
October 1, 1913		Accumulated	storage as-	sumed to be		0
1913-14	32,400		37,200		4,800	−4,800
1914-15	59,200		37,200	22,200		17,400
1915-16	142,000		37,200	104,800		122,200
1916-17	21,300		37,200		15,900	106,300
1917-18	23,500		37,200		13,700	92,600
1918-19	14,000		37,200		23,200	69,400
1919-20	24,000		37,200		13,200	56,200
1920-21	14,300		37,200		22,900	33,300
1921-22	94,000		37,200	56,800		90,100
1922-23	18,500		37,200		18,700	71,400
1923-24	13,900		37,200		23,300	48,100
1924-25	11,700		37,200		25,500	22,600
1925-26	22,100		37,200		15,100	7,500
1926-27	51,700		37,200	14,500		22,000
1927-28	17,300		37,200		19,900	2,100

TABLE 42. ESTIMATED RESERVOIR AND GRAVEL STORAGE—LOWER BASIN

In acre-feet

Year	1	2	3	4	5	6
	Retained annually in Basin		Consumptive use and natural losses as of 1928	Resulting storage		Accumulated reservoir and gravel storage
	Gain	Deficiency		Increase	Decrease	
October 1, 1913		Accumulated	storage as-	sumed to be		0
1913-14	207,300		170,500	36,800		36,800
1914-15	254,300		170,500	83,800		120,600
1915-16	386,000		170,500	215,500		336,100
1916-17	130,300		170,500		41,200	294,900
1917-18	148,900		170,500		21,600	273,300
1918-19	93,500		170,500		77,000	196,300
1919-20	128,400		170,500		42,100	154,200
1920-21	110,300		170,500		60,200	94,000
1921-22	348,100		170,500	177,600		271,600
1922-23	135,500		170,500		35,000	236,600
1923-24	93,800		170,500		76,200	159,900
1924-25	67,900		170,500		102,600	57,300
1925-26	98,600		170,500		71,900	−14,600
1926-27	208,700		170,500	38,200		23,60[illegible]
1927-28	145,000		170,500		25,500	−1,90[illegible]

ESTIMATED ESCAPE OF UNDERGROUND AND SURFACE WATERS INTO THE OCEAN

Surface Escape of Santa Ana River. The major portion of the run-off of the Santa Ana River entering the sea is measured at U. S. Geological Survey Fifth street gaging station at Santa Ana. Although this station is eight miles from the coast, it is here considered to represent the discharge into the ocean. The channel below the station is confined by levees. Comparative measurements at low stages show no loss in the direction of the ocean.

The remainder of the run-off of the Santa Ana River is that portion which has historically broken levees and found its way into the ocean, via the San Gabriel River, the old Anaheim channel or across country. This was estimated as 7100 acre-feet for the flood of the season 1926–27 after field measurement of flood evidence and utilizing data furnished by W. W. Hoy.

The following gives the escape into the ocean from the Santa Ana River for the seasons of 1926–27 and 1927–28:

Season	*Acre-feet*
1926–27	67,000
1927–28	1,530
15-year mean, estimated as in Table 34	44,700

Carbon and Brea Canyons, Fullerton Foothill Area and Old Anaheim Channel. Carbon and Brea canyons drain into Coyote Creek, and thence into the San Gabriel River and the ocean. Old Anaheim channel carried flood water only in 1926–27. The estimated escape into the ocean for these streams is as follows:

Season	*Acre-feet*
1926–27	12,400
1927–28	0
15-year mean, estimated	3,600

Drainage Ditches at Mouth of Santa Ana River and Northward. Reconnaissance showed 11 ditches leading into the coastal marshes. Gaging stations were established in 1927 on all of these ditches. These ditches are largely open cuts which serve to carry off the storm run-off of the valley floor, as well as drain numerous tile drainage systems. The total area under these drainage systems is estimated at 82 square miles. The following shows the estimated run-off from these ditches:

Season	*Acre-feet*
1926–27 (including levee break of 7100 acre-feet from Santa Ana River)	15,440
1927–28	5,115
15-year mean, for present conditions, estimated	6,300

Drainage Water and Run-off Into Newport Estuary. Reconnaissance showed two ditches entering the estuary, and gaging stations were established on both in 1927. The estimated area drained by these ditches is nine square miles. The following shows the estimated run-off from these ditches:

Season	*Acre-feet*
1926–27	5,300
1927–28	2,100
15-year mean, for present conditions, estimated	2,600

Escape of Underflow. Test borings by Irvine Ranch Company indicate that the underground formation is tight and no underflow is probable into the Newport Estuary. It is considered negligible in this study. A special geological examination was made in May, 1928, of the formations near the coast. The dominant points are:

The Dominguez Ridge is a well-known anticline parallel to the coast, its axis being about one mile inland. This ridge is composed of material which may be considered tight, except where it has been pierced by three gaps or passes aggregating seven miles in length.

In geological history this ridge was elevated some 300 feet during which the Santa Ana River persisted through the gaps. Subsidence to the present day again through 300 feet, resulted in a detrital back-fill of these gaps. It is the amount of probable underflow through these detrital filled gaps, which is the subject of this study. Plate 11, page 211, "Section Along Dominguez Ridge," and Plate 12, page 212, "Hydrographic Profile Near Mouth of Santa Ana River," indicate the situation.

There are three depressed gaps, the Santa Ana, Las Bolsas, and Anaheim, and the problem is to determine the quantity of pressure water escaping to the ocean.

In the case of the Santa Ana depressed gap there is detailed information of the hydraulic elements across the ridge, on which an estimate can be made. On the other gaps complete information is lacking on account of marsh areas. For these gaps the factors determined on the Santa Ana gap are taken to apply, based on the theory of the similar deposition of the sediments.

The Sectional Area of the Gaps. The well records indicate two water tables, a perched water zone and a pressure zone. The well logs indicate that it is necessary to go over 80 feet before perforations yield pressure water. Therefore the sections are divided into zones as follows:

Zone A—Upper 80 feet related to perched water table.

Zone B—A tighter material containing lenses of water-bearing gravel under pressure.

The following gives these sectional areas in square feet:

Name of gap	*Width Miles*	*Maximum depth feet*	*Zone B square feet*
Santa Ana	2.6	320	1,700,000
Bolsa Chica	1.8	290	2,000,000
Anaheim	2.6	300	2,700,000

Calculation of Quantity of Water Escaping Through Santa Ana Gap. The first inquiry considers whether there could be any escape at all. From one point of view the "seal" of 80 feet of tight material may be expected to have continued under the ocean, and now lies covered with the present muds. In other words, there is a reasonable doubt if the strata of the deep water-bearing gravels outcrops under the ocean floor.

Disregarding the above possibility of complete or partial sealing, the answer was sought under the assumption that pressure strata outcrop under the ocean floor. For this solution the Slichter formula was used. To determine the transmission constant "K" in that formula, a preliminary study of the pumping extractions in the Santa Ana gap was made. The following data was collected from field observations made in May 1928.

SANTA ANA GAP

Total width of gap	2.6 miles
Cross-sectional area of pressure zone	1,700,000 square feet
As the pumped wells are mostly grouped in the south half of section, take for calculation	800,000 square feet
General gradient of pressure 3 feet per mile or	6/100 of 1 per cent
Gradient of pressure in vicinity of pumping 10 feet per mile or	19/100 of 1 per cent
Average quantity of water extracted	3.4 second-feet
Transmission constant "K" as defined by Slichter and calculated from above data	0.13
If a porosity of 33 per cent is assumed, the above value is equivalent to a velocity through the voids, for this gradient	1.1 foot per day

Calculation of All Gaps. The transmission constant so determined if applied to all the gaps will give the following result, neglecting pumping effects.

Total sectional area	6,400,000 square feet
Transmission constant "K" as defined by Slichter	0.13
Gradient of water plane	6/100 of 1 per cent
Resulting discharge 512 cubic feet per minute or	8.5 second-feet

Conclusion as to Escape by Underflow Through Pressure Zone. The constant pumping in the vicinity of Newport, in the Santa Ana gap, of 3.4 second-feet lowers the water plane slightly below sea level in that gap. There is presumably no escape in this portion, which has been assumed to cover 800,000 square feet. If the escape were a large proportion of the water traveling underground toward the ocean, artesian pressure would be small. However, the fact that only three or four second-feet can be pumped shows that the water reaching this vicinity is small in amount. It is concluded that the outflow underground for all the gaps is not more than 8000 acre-feet annually, even if the strata under the ocean are open. This quantity is used in the hydrographic tables.

While the estimate of 8000 acre-feet underflow into the ocean is made by a logical method yet the situation is so obscure that time alone will demonstrate whether this quantity or any quantity of water actually flows into the ocean. If a flow exists it will be demonstrated by an influx of salt water when and if the gradient of water plane or pressure plane toward the ocean is reversed through further lowering of the present levels by pumping.

Escape of Sewage. The metropolitan sewerage system discharges into the ocean near the outlet of the Santa Ana River. This is the united sewage of Santa Ana, Orange, Anaheim, Fullerton and three other sanitary districts. The mean flow in 1927 was approximately five second-feet or 3600 acre-feet.

Summary of Estimated Mean Escape into the Ocean for 15-year period—1913-1928

	Acre-feet
Surface run-off Santa Ana River, at Santa Ana, Fifth Street Station, U. S. G. S.	44,700
Surface run-off Carbon and Brea Canyons	3,600
Drainage ditches at mouth of Santa Ana River and northward	6,300
Drainage water and run-off into Newport Estuary	2,600
Underflow	8,000
Sewerage	3,600
Total	68,800

Infiltration of Sea Water. A correlated question is whether, by future heavy extraction within the Dominguez Ridge, salt water would appear. The answer is that the hydraulic gradient would have to be reversed. However, salt water has not appeared on wells in the Santa Ana gap, with a reversed gradient of three feet per mile. On the same gradient pressure wells 10 miles inland would have to be lowered 60 feet before the salt infiltration would appear probable.

TABLE 43. LOGS OF WELLS IN VICINITY OF SANTA ANA GAP USED IN DETERMINING PROFILE AND ARRANGEMENT OF MATERIALS

Letter C indicates well is within U. S. G. S. Corona Quadrangle

Well C-291		Well C-292		Well C-287	
Depth in feet	Material	Depth in feet	Material	Depth in feet	Material
0–12	Loam	0–8	Loam	0–85	
12–85	Sea mud	8–85	Sea mud	85–110	Sand and gravel
85–97	Sand and gravel	85–95	Fine sand	110–400	Shale
97–160	Good gravel	95–140	Gravel		
160–410	Blue clay	140–178	Clay		
		178–190	Clay		

Well C-285		Well C-265D		Well C-265E	
Depth in feet	Material	Depth in feet	Material	Depth in feet	Material
0–85		0–10	Soil	0–6	Soil
85–110	Sand and gravel	10–30	Shells	6–96	Sandy clay
110–135	Clay	30–90	Clay	96–100	Sand
135–145	Sand and gravel	90–145	Fine gravel	100–204	Gravel
145–400	Clay	145–190	Good gravel	204–220	Sand
		190–216	Clay	220–323	Clay
		216–256	Gravel		
		256–270	Clay		

Well C-296	
Depth in feet	Material
0–20	Soil
20–65	Blue clay
65–101	Sand and gravel
101–172	Blue clay
172–174	Fine gravel
174–222	Coarse gravel
222–265	Fine gravel
265–314	Coarse gravel
314–325	Fine gravel
325–332	Blue shale

LOGS OF WELLS IN VICINITY OF BOLSA CHICA GAP USED IN DETERMINING PROFILE AND ARRANGEMENT OF MATERIALS

Letter M indicates Mendenhall, U. S. G. S. water supply papers

Well M-183		Well M-175		Well M-63	
Depth in feet	Material	Depth in feet	Material	Depth in feet	Material
				0–18	Top soil and sand
57–65	Medium coarse gravel	120–123	Coarse gravel	18–40	Blue clay
				40–42	Gravel
		265–281	Gravel	42–44	Gravel
				44–72	Fine sand
				72–80	Gravel

LOGS OF WELLS IN VICINITY OF BOLSA CHICA GAP USED IN DETERMINING PROFILE AND ARRANGEMENT OF MATERIALS—Continued

Letter M indicates Mendenhall, U. S. G. S. water supply papers

Well M-78		Well M-246		Well M-247	
Depth in feet	Material	Depth in feet	Material	Depth in feet	Material
0–30	Peat	181–193	Blue clay		
		193–197	Gravel	245–247	Gravel

Well M-64		Well M-97	
Depth in feet	Material	Depth in feet	Material
0–65	Peat	0–3	Shell deposit
65–72	Gravel	3–8	Red mesa soil
		8–18	Gravel
		18–100	Sand and shell
		100–132	
		132–138	Gravel

LOGS OF WELLS IN VICINITY OF ANAHEIM GAP USED IN DETERMINING PROFILE AND ARRANGEMENT OF MATERIALS

Well M-298		Well M-297		Well M-299	
Depth in feet	Material	Depth in feet	Material	Depth in feet	Material
0–10	Clay	0–20	Blue clay	0–100	Mostly clay
10–50	Beach sand	20–26	Fine water sand	100–104	Light water gravel
50–124	Clay	26–104	Blue clay	104–178	Blue clay
124–152	Gravel	104–120	Medium coarse gravel	178–190	Mostly gravel

Well M-169		Well M-28A		Well M-48	
Depth in feet	Material	Depth in feet	Material	Depth in feet	Material
0–10	Soil	0–40	Hard yellow clay		
10–50	Blue clay	40–50	Fine sand		
50–150	Quicksand and narrow clay strata	50–100	Yellow clay	70–80	Gravel
150–212	Beach sand and shells	100–250	Fine sand		
212–218	Soft clay			?–180	Gravel
218–226	Hard sand				
226–234	Quicksand				
234–250	Soft blue clay				
250–258	Sand and pebbles				
258–266	Blue sand				
266–276	Sand and pebbles				
276–292	Fine gravel				
292–302	Blue sand				

LOGS OF WELLS IN VICINITY OF ANAHEIM GAP USED IN DETERMINING PROFILE AND ARRANGEMENT OF MATERIALS—Continued

Well M-5		Well M-9		Well M-14	
Depth in feet	Material	Depth in feet	Material	Depth in feet	Material
0–6	Sand loam				
6–42	Blue clay				
42–45	Gravel	90–170	Beach sand	77–87	Gravel
45–100	Clay and sand				
100–120	Fine sand			190–198	Very coarse sand

Well M-134	
Depth in feet	Material
0–15	Top soil
15–25	Peat
25–70	Beach sand
70–80	Blue cement clay
80–92	Gravel
92–200	Beach sand
200–212	Gravel
212–230	Blue cement
230–232	Gravel

PLATE 11

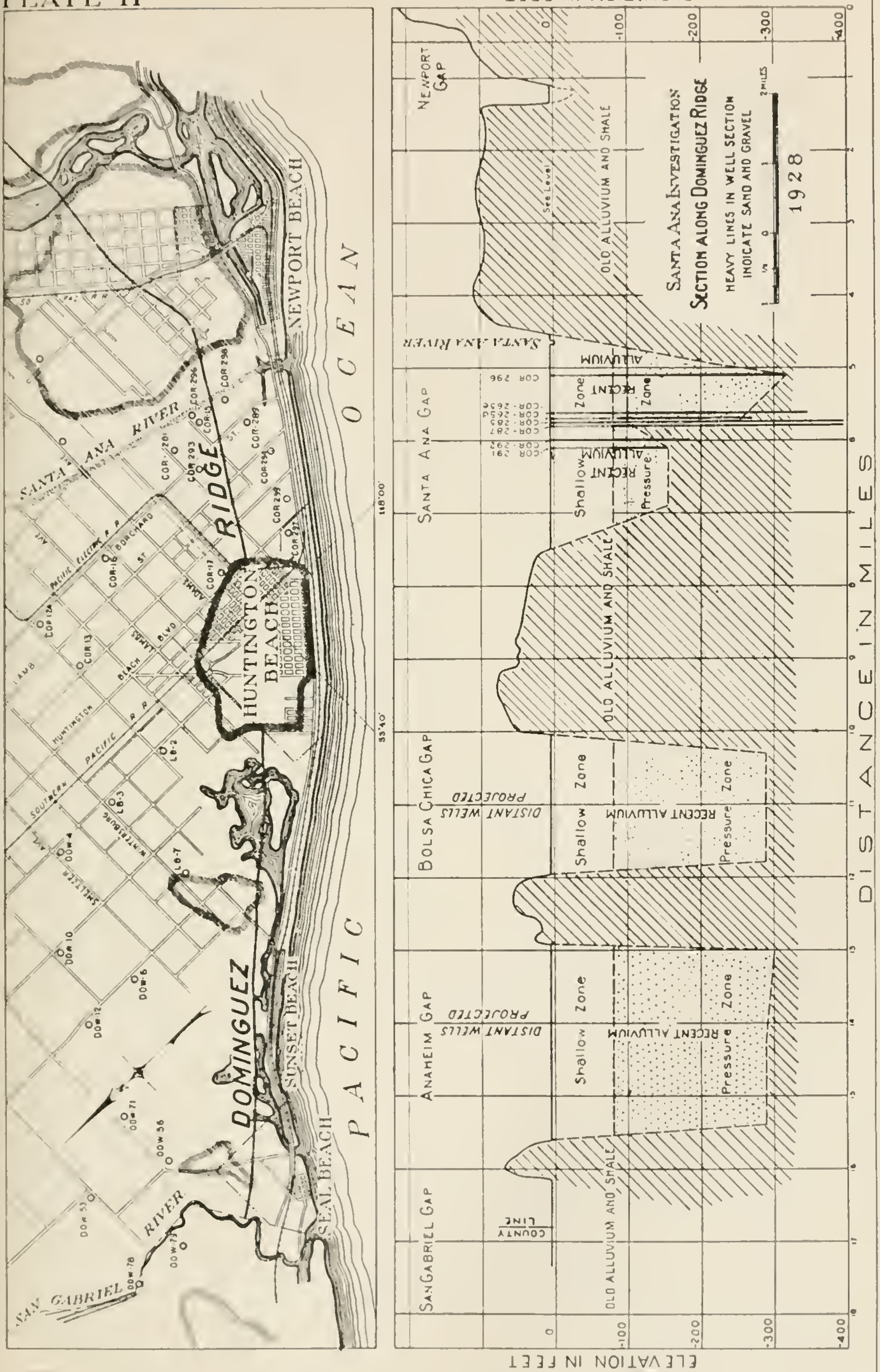

SANTA ANA INVESTIGATION
SECTION ALONG DOMINGUEZ RIDGE
HEAVY LINES IN WELL SECTION INDICATE SAND AND GRAVEL
1928
ELEVATION IN FEET
DISTANCE IN MILES
NEWPORT GAP
SANTA ANA GAP
BOLSA CHICA GAP
ANAHEIM GAP
SAN GABRIEL GAP
SANTA ANA RIVER
OLD ALLUVIUM AND SHALE
RECENT ALLUVIUM
Shallow Zone
Pressure Zone
DISTANT WELLS PROJECTED
COUNTY LINE
Sea Level
PACIFIC OCEAN
NEWPORT BEACH
HUNTINGTON BEACH
SUNSET BEACH
SEAL BEACH
DOMINGUEZ RIDGE
SANTA ANA RIVER
SAN GABRIEL RIVER

PLATE 12

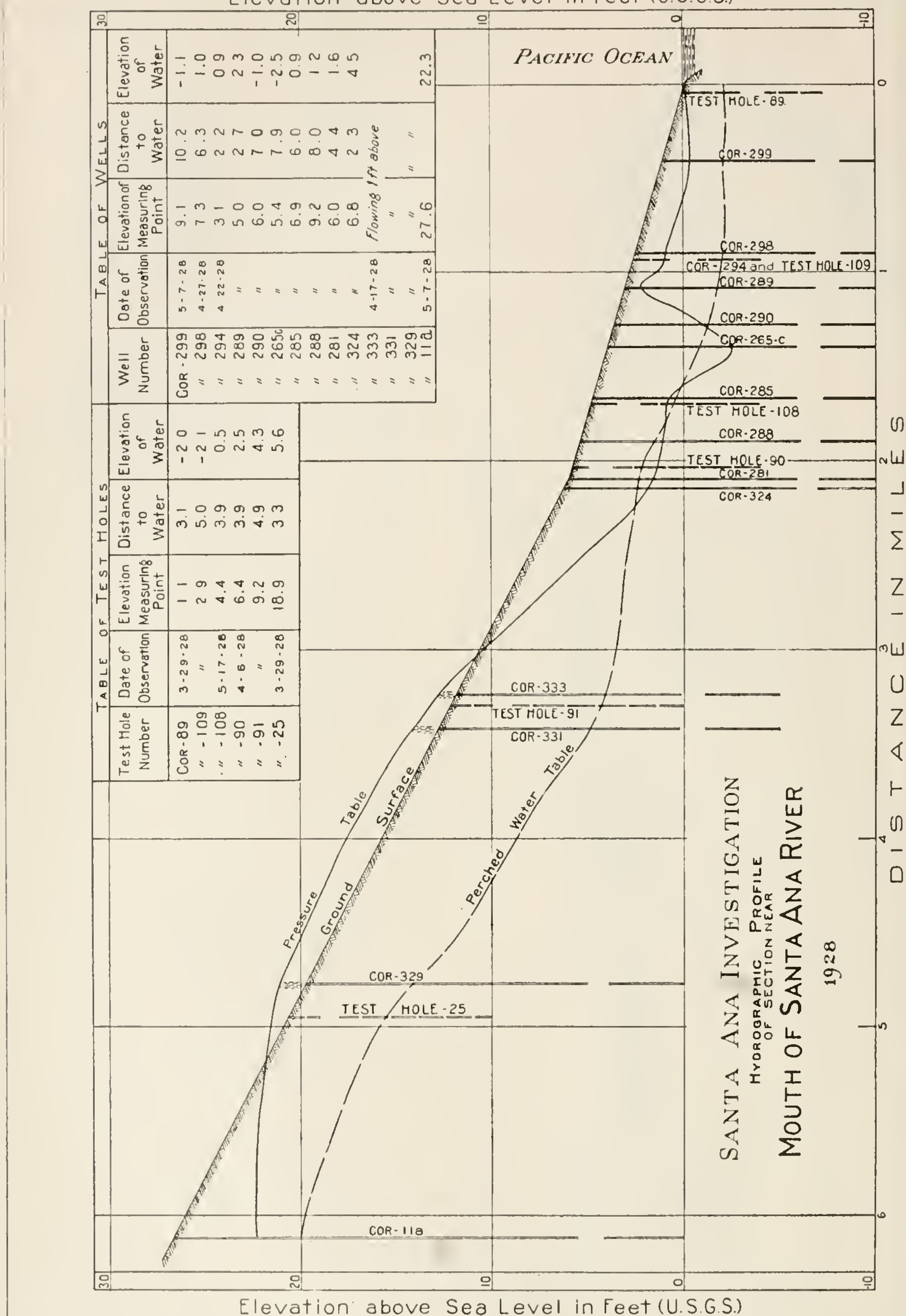


TABLE OF WELLS

Well Number	Date of Observation	Elevation of Measuring Point	Distance to Water	Elevation of Water
COR-299	5-7-28	9.1	10.2	-1.1
" 298	4-27-28	7.3	6.3	1.0
" 294	4-22-28	3.1	2.2	0.9
" 289	"	5.0	2.7	2.3
" 290	"	6.0	7.0	-1.0
" 265c	"	5.4	7.9	-2.5
" 285	"	6.9	6.0	0.9
" 288	"	9.2	8.0	1.2
" 281	"	6.0	4.4	1.6
" 324	"	6.8	2.3	4.5
" 333	4-17-28	Flowing 1 ft above		
" 331	"	"	"	
" 329	"	"	"	
" 11a	5-7-28	27.6		22.3

TABLE OF TEST HOLES

Test Hole Number	Date of Observation	Elevation Measuring Point	Distance to Water	Elevation of Water
COR-89	3-29-28	1.1	3.1	-2.0
" -109	"	2.9	5.0	-2.1
" -108	5-17-28	4.4	3.9	0.5
" -90	4-6-28	6.4	3.9	2.5
" -91	"	9.2	4.9	4.3
" -25	3-29-28	18.9	3.3	5.6

SEWAGE UTILIZATION FOR IRRIGATION

The city of Los Angeles maintains an outfall sewer discharging into the ocean at Hyperion on Santa Monica bay. This is distant 24 miles from the Orange County line in an airline. The quantity for the fiscal year 1927–28 is an average of 86,000,000 gallons daily, or 132 second-feet, or 95,000 acre-feet. The Los Angeles County Sanitation District maintains a plant six miles west of Long Beach. The quantity of sewage is 3,500,000 gallons daily, or five second-feet, or 4000 acre-feet.

The joint sewer project of Orange County, as of today, discharges an average of seven second-feet, or 5000 acre-feet into the ocean.

In the present state of the art, the opinion is that the cost of treatment sufficient to comply with the minimum requirements of the State Board of Health, combined with cost of distribution, is so great that treated sewage can not compete with ordinary well sources for irrigation. That is, the financial side is considered to be conclusive, irrespective of technical considerations. From the financial standpoint it is indicated that the interest on the first cost, or plant investment for activated sludge treatment, plus the operating cost, would amount to $20 per acre-foot. To this would be added the cost of pumping and the interest on the cost of pipe lines to convey the treated effluent from the plant to the irrigated lands. If this conveyance charge be arbitrarily taken at $20 per acre-foot, the cost of treated effluent delivered would reach $40 per acre-foot. This illustrates the financial side of the question.

On the technical side present practice provides screening for solids, resulting in a removal of 5 to 15 per cent. Activated sludge treatment removes 99 per cent of the organic matter, but leaves in solution practically all the mineral salts. For use for irrigation, health regulations may require chlorine treatment for removal of pathogenic bacteria. While these processes are known to be effective in preparing sewage for disposal in the usual ways without causing a nuisance, nevertheless at this time it cannot be said that the art of sewage disposal has advanced to the point that the effluent is equivalent either pathogenically or chemically of a fresh water supply. This is the technical attitude.

Political, legal and social considerations are obviously inherent in this problem. Any action regarding the use of the sewage of one community by another requires the joint action of the governing bodies of these communities. The responsibility as to public health can not be avoided. If, as is possible, deleterious minerals are introduced into the ground water, damage might arise with a new responsibility for pollution, irrespective of compliance with sanitary laws.

PROPOSED LOS ANGELES-COLORADO RIVER AQUEDUCT PROJECT †

* * * * * * *

Los Angeles now has a population of 1,230,000, and has been growing at a rate which has averaged over 70,000 inhabitants per year for the last 10 years. A careful investigation of its present water resources shows that it will reach the limit of its supply within 10 years.

Also, in the vicinity of Los Angeles are many suburban cities, some of which are increasing in population with an even greater rapidity than that city itself. Some of these cities even now feel the pinch of water shortage, and many of them see the limit of their water supply being reached within a comparatively short period of time.

In order that these smaller cities may participate in the Los Angeles-Colorado River project, an Act providing for the formation of metropolitan water districts for the purpose of developing, storing, and distributing water for domestic purposes, was recently passed by the legislature of the State of California. Under this act such a district may be formed of the territory included within the corporate boundaries of any two or more municipalities.

* * * * * * *

A route originating 15 or 20 miles above Blythe, California, has been favored by Mr. Mulholland (chief engineer and general manager of Los Angeles Bureau of Water and Supply). This route has many attractive features, and most of it can be constructed with little difficulty. It has been surveyed and examined in greater detail than any other of the routes proposed. Commencing with an intake approximately due east from Los Angeles, and at practically the nearest point on the river to that city, the route skirts the southern end of the Maria Mountains in Riverside County, California, for a distance of from 10 to 15 miles. Then by successive lifts and grade conduits, alternately, the line is to be carried to the divide between the Colorado River Basin and the Coachella Valley of California. This divide is locally known as Shaver's Summit. The total difference in elevation to be overcome in reaching Shaver's Summit is about 1400 feet, to which must be added friction head. This would be accomplished in the first 75 miles of aqueduct. In order to overcome this difference in head with the least construction and operating difficulties, the lifting will be done in five stages. From Shaver's Summit to the end of the route, no further pumping will be required.

Between Shaver's Summit and Los Angeles, it will be necessary to construct approximately 35 miles of concrete lined tunnels along the southwesterly face of the Little San Bernardino Mountains. There will also be a long tunnel under San Gorgonio Pass, varying from 13 to 27 miles in length, depending on its exact location, which has not as yet been fully determined. From the westerly portal of this tunnel, grade conduit and tunnels will complete the line to Los Angeles.

Along the river front and parallel with the easterly portion of this route are extensive gravel deposits, where it is believed that a sufficient quantity of clear water for the first few years of operation of the aqueduct can be obtained, either by means of the construction of a large infiltration channel below the water plane, or by pumping from wells suitably placed, or by both.

The adequacy of these gravels as a preliminary source of supply is to be thoroughly tested by pumping from a two-mile section of full sized infiltration canal, and from wells drilled at various points along the river front. Up to the present time about three-fourths of the length of the canal has been excavated, and 12 wells have been drilled to depths varying from 60 to 200 feet.

As a result of the construction of a high dam either at Black or Boulder canyon, it is believed that when a greater supply is needed, the river will be sufficiently desilted at the proposed point of intake to permit of its being pumped directly into the aqueduct. If, however, this is not the case, it can readily be rendered clear and potable by the usual methods of mechanical filtration.

* * * * * * *

In operating an aqueduct of this character, the main item of cost is that of the power necessary for pumping. To date this latter cost has not been fixed, although for the purpose of carrying on economic studies, it has been assumed that power

† Extract of a paper prepared by Mr. E. A. Bayley, Assistant Engineer for Mr. H. A. Van Norman, Assistant Chief Engineer and General Manager of the Bureau of Water Works and Supply of the Department of Water and Power of the city of Los Angeles, presented at the Irrigation Division Meeting of the American Society of Civil Engineers, Denver, Colo., July 14, 1927.

will be available at the rate of three mills per kilowatt hour. This price is one for which it is estimated power can be sold at the switchboard of a power plant situated either at Boulder or Black Canyon dam sites, with a dam constructed 600 feet in height above the low water level of the river. In all studies due credit is given to an estimated possible income derived from the sale of return power at the westerly end of the proposed aqueduct, wherever head is available for that purpose.

As to the quantity of water to be pumped upon the completion of the aqueduct project, studies have been made as to the rate of growth of the population of all such cities of southern California as may reasonably be expected to participate in the benefits of this aqueduct. Their domestic needs have been carefully studied, and after deducting their present supply, the deficiencies have been assumed as being supplied from the Colorado River.

The cost of pumping this water both annually, and in total throughout the years, together with the interest charges and installments of principal that will have to be borne by the population to be served, has been computed as carefully as such data can be.

* * * * * * *

The quantity of water ultimately to be diverted is 1500 cubic feet per second. The line when on hydraulic grade will be in excavation, and completely covered throughout its length. When below hydraulic grade it will be either steel pipe or reinforced concrete, with possibly a pressure tunnel under San Gorgonio Pass. All tunnels will be concrete lined. The type of construction for grade conduits which is proposed is similar to that used on the Catskill aqueduct. Where the nature of the ground surface shows it advisable to dip below hydraulic grade and locate under light pressure, a reinforced concrete hydrostatic chord type similar to the Ontario Power Company's 18-foot conduit may be adopted. Under heavier pressure, steel pipe lines will be used. Due to the frequency of cloudbursts on the desert area to be traversed, the adoption of either an open conduit or a so-called cut and cover section blocking cross drainage is not considered advisable. Pumping plants, pressure mains and inverted siphons will be constructed in units as required.

Owing to the steepness of the slopes prevailing in the coastal plain of southern California, there are few large reservoir sites available for regulating and distributing purposes at that end. The city of Pasadena has a proposed reservoir in San Gabriel Canyon, near Azusa, California, which if constructed, would store 65,000 acre-feet of water. The Los Angeles County Flood Control District also contemplates the construction of a resorvoir near San Dimas, California, in what is known as the Puddingstone reservoir site. It would be capable of storing at least 16,000 acre-feet, in addition to that required for flood control purposes. Both of these proposed reservoirs are situated at elevations which would make them practical for storage and distributing purposes, and all studies so far made, contemplate maintaining the grade line at such elevation as to make use of either, if available.

CHAPTER 9

IRRIGATION AND DOMESTIC UTILIZATION; DUTY OF WATER; MONTHLY DEMAND; SERVICE ORGANIZATIONS

Irrigated and Domestic Acreage. In 1926 a field survey of irrigated and domestic area was made. This survey, partially revised in 1927 and 1928, is delineated on Map 6, in pocket. The results of this map acreage are shown in Table 4, page 98, giving 25,282 acres of domestic use and 342,700 acres of irrigation, a total of 367,982 acres.

Duty of Water. The adopted duty of water on various crops is shown in Table 44. These values are generalized from local opinion and published reports. The average duty for the various basins as of 1928, for the map acreage delineated on Map 6 is:

	Duty of water
Upper Basin	1.84
Jurupa	2.08
Cucamonga	.86
Temescal	1.87
Lower Basin	1.52

Monthly Demand. The monthly demand is defined as the amount used in each month. In Table 45, page 218, this monthly demand is expressed as a percentage of the yearly demand or use. This table is derived entirely from the monthly variation of electricity and gas consumed and is representative of the demand as used by pumping plants, for the various basins. There is also shown the monthly demand for certain pumping, gravity and combined systems, over smaller areas.

Water Organizations. In Table 46, page 219, is given a list of the major water organizations operating in the watershed.

TABLE 44. DUTY OF WATER, ADOPTED AVERAGE VALUES
Upper Basin

Crop	Acres	Duty	Water applied in acre-feet
Apples and cherries	600	1.5	900
Deciduous	1,600	1.5	2,400
Citrus	19,900	2.5	49,700
Walnuts	100	2.0	200
Vines	1,000	1.0	1,000
Truck	500	1.5	750
Unclassified, mostly grass lands, subirrigated	5,400	1.67	9,018
Domestic areas	6,372	1.5	9,560
Irrigated within city limits	7,410	2.0	14,800
Yucaipa and Beaumont valley	11,860	1.0	11,860
Totals	54,742	1.84	100,188

Jurupa Basin

Crop	Acres	Duty	Water applied in acre-feet
Domestic	2,910	1.5	4,370
Citrus	21,903	2.5	54,800
Deciduous	1,822	1.5	2,740
Apples and cherries	798	1.0	798
Walnuts	1,012	2.5	2,530
Vines	985	1.0	985
Truck	846	1.5	1,270
Alfalfa	2,951	3.0	8,870
Unclassified	12,190	1.5	18,330
Totals	45,420	2.08	94,693

Cucamonga Basin

Crop	Acres	Duty	Water applied in acre-feet
Domestic	3,280	1.5	4,920
Citrus	17,184	2.0	34,368
Deciduous	11,787	1.0	11,787
Apples and cherries	758	1.0	758
Walnuts	4,181	2.0	8,362
Vines	31,617	.5	15,808
Truck	1,540	1.5	2,310
Alfalfa	1,440	2.5	3,600
Unclassified	30,269	----	5,960
Totals	102,056	.86	87,873

Temescal Basin

Crop	Acres	Duty	Water applied in acre-feet
Domestic	1,090	1.5	1,635
Citrus	7,193	2.0	14,390
Deciduous	929	1.5	1.390
Apples and cherries	139	1.5	208
Walnuts	643	2.5	1,610
Vines	439	1.0	439
Truck	857	1.5	1,290
Alfalfa	3,300	3.0	9,900
Miscellaneous	3,710	1.5	5,565
Totals	18,300	1.87	36,427

Lower Basin

Crop	Acres	Duty	Water applied in acre-feet
Domestic	10,970	1.50	16,500
Citrus	51,900	2.00	103,800
Deciduous	1,555	1.00	1,555
Apples and cherries	550	1.00	550
Walnuts	15,400	2.00	30,800
Vines	250	.50	125
Truck	5,700	1.00	5,700
Alfalfa	3,000	2.50	7,500
Unclassified	58,139	1.00	58,139
Totals	147,464	1.52	224,669

TABLE 45. MONTHLY DEMAND FOR IRRIGATION AND DOMESTIC WATER BY BASINS DURING 1927 AS INDICATED BY MONTHLY GAS AND ELECTRIC CONSUMPTION

(Expressed in percentage of yearly demand)

Basin	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Upper	.9	.9	.9	.9	5.6	14.7	17.9	18.9	18.3	14.5	5.1	1.4
Jurupa	.7	.7	.7	1.4	5.7	14.1	18.6	19.4	17.9	14.1	5.3	1.5
Cucamonga	1.0	1.0	.8	1.3	3.7	13.3	18.5	19.2	17.5	14.9	7.4	1.4
Temescal	.3	1.3	.9	1.4	8.0	15.4	17.1	17.9	17.0	13.6	4.5	2.0
Lower	2.0	1.8	1.4	1.6	3.5	13.9	15.2	19.7	19.0	13.7	6.2	2.0

MONTHLY DEMAND FOR IRRIGATION ON 1,000 ACRES OF CITRUS IN CUCAMONGA BASIN SUPPLIED BY PUMPING

(Expressed in percentage of yearly demand)

Year	Duty acre-feet	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1925	2.70	3.5	3.3	6.1	2.0	10.5	13.7	14.4	14.2	13.1	7.9	9.9	1.4
1926	2.90	5.3	.2	2.9	1.1	6.8	13.3	15.4	14.8	14.8	14.3	10.8	.3
1927	2.44	.3	.4	.5	.5	8.5	16.7	18.3	18.9	17.4	14.6	1.5	2.3
Mean	2.71	3.0	1.3	3.2	1.3	8.6	14.6	16.0	15.9	15.1	12.3	7.4	1.3

MONTHLY DEMAND IN 1927 FOR IRRIGATION BY GRAVITY AND COMBINED GRAVITY AND PUMPING SUPPLIES

(Expressed in percentage of yearly demand)

	Source	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Upper Basin:													
For 300 acres	Gravity	.0	.1	.0	1.3	22.4	27.9	17.4	10.2	8.7	5.8	1.9	4.3
For 1,800 acres	Gravity with storage	1.2	1.1	7.6	9.5	8.8	11.2	13.9	13.9	12.4	10.4	9.0	1.0
Jurupa Basin:													
For 7,000 acres	Gravity and pumping	.6	.5	.0	3.0	14.5	16.8	17.6	16.8	15.1	12.4	.6	2.1
Lower Basin:													
For 16,200 acres	Gravity and pumping	2.0	2.4	.6	2.5	15.3	19.4	16.3	17.5	11.6	10.1	.0	2.3
For 2,700 acres	Gravity	4.3	2.3	2.9	6.5	14.8	12.6	17.1	12.8	9.9	8.2	5.3	3.3

TABLE 46. LIST OF WATER ORGANIZATIONS OPERATING IN SANTA ANA WATERSHED

Upper Basin

Service area No.	Service organization	Kind of service	Source of supply
1	City of San Bernardino	Domestic	Combined
2	Mount Vernon Water Company	Irrigation	Combined
3	City of Redlands	Domestic	Underground
	City of Redlands	Irrigation	Underground
4	Bear Valley Mutual Water Company	Irrigation	Gravity
	North Fork	Irrigation	Gravity
	Del Rosa	Irrigation	Gravity
	Highland Domestic Water Company	Irrigation	Gravity
	Lugonia	Irrigation	Gravity
	East Lugonia	Irrigation	Gravity
	Mentone Water Company	Irrigation	Gravity
	Crafton Water Company	Irrigation	Gravity
	West Redlands	Irrigation	Gravity
	Redlands Heights	Irrigation	Gravity
	South Mountain	Irrigation	Gravity
5	Muscoy Mutual Water Company	Irrigation	Underground
6	East Highland Water Company	Irrigation	Combined
	Plunge Creek	Irrigation	Combined
	East Highland Domestic	Irrigation	Combined
7	City Creek Water Company	Irrigation	Gravity
8	Yucaipa Water Company No. 1	Irrigation	Combined
	Yucaipa	Domestic	Combined
9	Beaumont Irrigation District	Irrigation and domestic	Combined
10	South Mesa Water Company	Irrigation	Underground
11	Western Heights Water Company	Irrigation	Underground
12	Unorganized	Irrigation	Underground

Jurupa Basin

Service area No.	Service organization	Kind of service	Source of supply
13	Lytle Creek Water and Improvement Company	Irrigation	Combined
14	City of Rialto	Domestic	Combined
15	Mutual Land and Water Company	Irrigation	Underground
16	Terrace Water Company	Irrigation	Underground
17	Citizens Land and Water Company	Irrigation	Underground
18	City of Colton	Domestic	Underground
19	Riverside Highland Water Company	Irrigation	Underground
20	City of Riverside	Domestic	Underground
21	Gage Canal	Irrigation	Combined
	East Riverside Water Company	Irrigation	Combined
	Citrus Experiment Station	Irrigation	Combined
	Temescal Water Company	Irrigation	Combined
	Alta Mesa Water Company	Irrigation	Combined
	Citizens Domestic Water Company	Domestic	Combined
22	Riverside Water Company	Irrigation	Combined
23	Unorganized	Irrigation	Combined

TABLE 46. LIST OF WATER ORGANIZATIONS OPERATING IN SANTA ANA WATERSHED—Continued

Cucamonga Basin

Service area No.	Service organization	Kind of service	Source of supply
24	Fontana Union Water Company	Irrigation	Combined
25	West Rialto Water Company	Irrigation	Underground
26	Marygold Water Company	Irrigation	Underground
27	West Riverside Canal	Irrigation	Underground
28	Etiwanda Water Company	Irrigation	Gravity
29	Rochester Water Company	Irrigation	Gravity
30	Cucamonga Water Company	Irrigation	Underground
----------	Old Settlers Water Company	Irrigation	Underground
----------	Sunset Water Company	Irrigation	Underground
----------	Alta Loma Mutual Water Company	Irrigation	Underground
----------	Citrus Water Company	Irrigation	Underground
31	Mountain View Water Company	Irrigation	Underground
32	City of Ontario	Domestic	Underground
33	Water Department of Pomona (within city limits); primarily Domestic; also served by Irrigation Company of Pomona	Domestic	Underground
34	Water Department of Pomona (within city limits); primarily Domestic; also served by individual irrigation plants	Domestic	Underground
35	Irrigation Company of Pomona (within city limits); primarily irrigation; also served domestic water by Water Department of Pomona	Irrigation	Underground
36	El Camino Water Company, Harrison Avenue Water Company (within city limits of Pomona); primarily irrigation; also served by Water Department of Pomona	Irrigation	Underground
37	Individual Ownership (within city limits of Pomona); primarily irrigation; also served by Water Department of Pomona	Irrigation	Underground
38	Water Department of Pomona (outside city limits of Pomona); area north of Philadelphia St., west of Central Ave., south of San Jose St., and east of city limits; primarily irrigation	Irrigation	Underground
39	El Camino Water Company (within city limits of Claremont) primarily irrigation; also served by Water Department of Pomona	Irrigation	Underground
40	Chino Water Company	Domestic	Underground
41	Unorganized ownership (within city limits of Claremont); primarily irrigation; also served by Water Department of Pomona	Irrigation	Underground
42	Claremont Domestic Water Company (within city limits of Claremont); primarily domestic; also served irrigation water by Claremont Cooperative Water Company	Domestic	Underground
43	Mont Clair Water Company (within city limits of Claremont)	Irrigation	Underground
44	Portion of Mont Clair Water Company (outside city limits of Claremont	Irrigation	Underground
45	Valley View Water Company	Irrigation	Underground
46	Boulder Water Company and Fairview Mutual Water Co.	Irrigation	Underground
47	Claremont Heights Irrigation Company	Irrigation	Underground
48	San Antonio Water Company	Irrigation and domestic	Combined
49	Hermosa Water Company	Irrigation	Combined
50	Iamosa Water Company	Irrigation	Combined
51	Unorganized	----------	----------

TABLE 46. LIST OF WATER ORGANIZATIONS OPERATING IN SANTA ANA WATERSHED—Continued

Temescal Basin

Service area No.	Service organization	Kind of service	Source of supply
52	Temescal Water Company	Irrigation	Combined
53	Corona City Water Company	Domestic	Combined
54	Orange Heights Water Company	Irrigation	Underground
55	Unorganized	Irrigation	Underground

Lower Basin

Service area No.	Service organization	Kind of service	Source of supply
56	Santa Ana Valley Irrigation Company	Irrigation	Gravity
57	City of Orange	Domestic	Underground
58	City of Santa Ana	Domestic	Underground
59	Anaheim Union Water Company	Irrigation	Gravity
60	City of Anaheim	Domestic	Underground
61	Yorba Linda Water Company	Irrigation	Underground
62	Carpenter Irrigation District	Irrigation	Gravity
63	Serrano Irrigation District	Irrigation	Gravity
64	City of Placentia	Domestic	Underground
65	City of Brea	Domestic	Underground
66	City of Fullerton	Domestic	Underground
67	Buena Park	Domestic	Underground
68	Garden Grove (unincorporated)	Domestic	Underground
69	Westminster (unincorporated)	Domestic	Underground
70	City of Seal Beach	Domestic	Underground
71	City of Huntington Beach	Domestic	Underground
72	Newport Mesa Irrigation District	Irrigation	Underground
73	Newport Heights Irrigation District	Irrigation	Underground
74	Cities of Newport and Balboa	Domestic	Underground
75	Unorganized	Irrigation	Underground

CHAPTER 10

RAINFALL RECORDS

The following Table 47 "Seasonal Rainfall 1926–27" shows the annual rainfall for 57 stations within the valley floor of the Santa Ana watershed. Of these, 11 stations are U. S. Weather Bureau stations, and 46 are maintained by individuals who have contributed the records to this investigation.

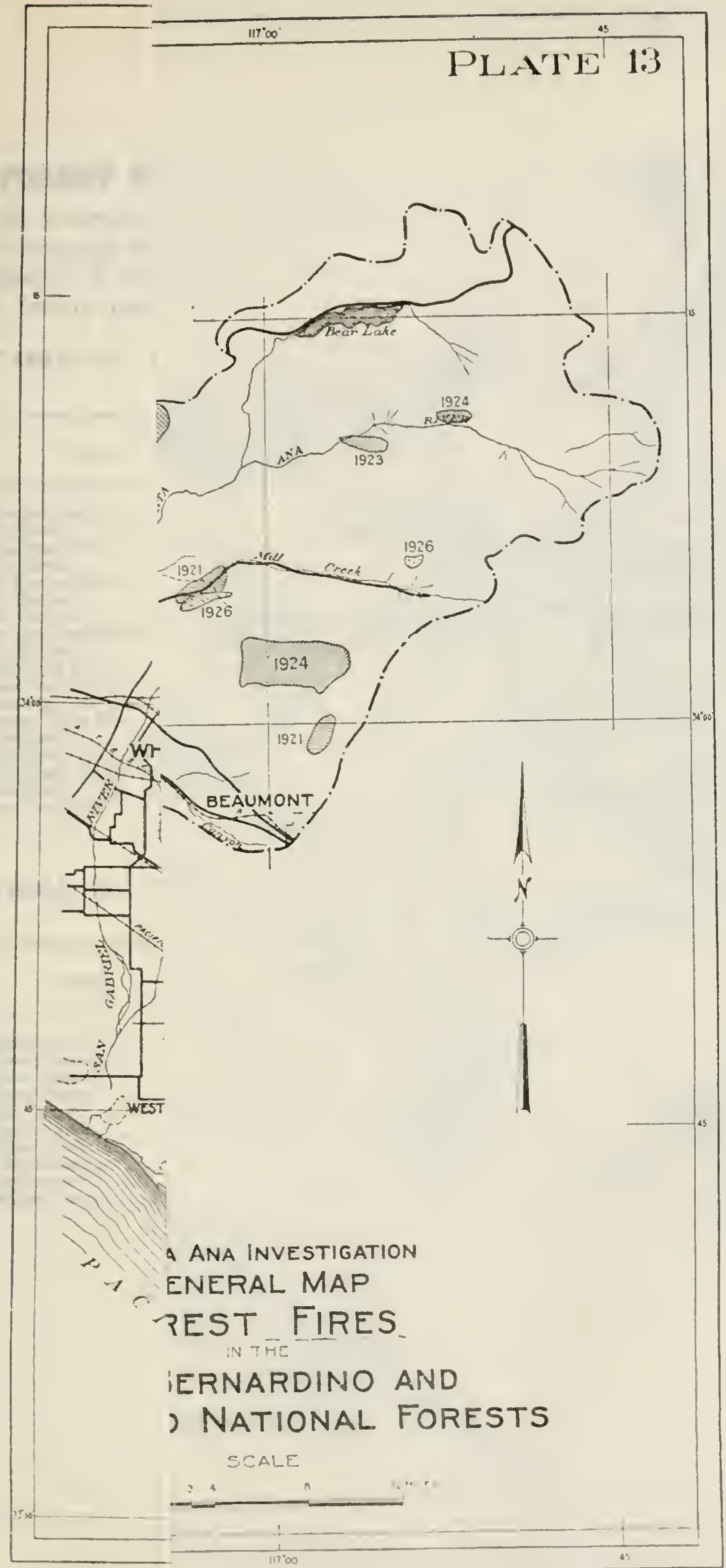
No records in the mountainous area are included. The stations given are those used in ascertaining rainfall penetration on the valley floor, as discussed in Section 4, page 152, and delineated on Map 11, in pocket, "Lines of Equal Rainfall."

TABLE 47. SEASONAL RAINFALL, 1926-1927

State No.	Locality and authority	Latitude	Longitude	Inches
21	Artesia, Griffen Lumber Company	33° 52′	118° 05′	14.83
22	Los Alamitos, Sugar Company	33° 49′	118° 04′	11.14
20	La Mirada, S. O. Company	33° 54′	118° 02′	14.65
47	Huntington Beach, Holly Sugar Corporation	33° 49′	118° 00′	13.43
18	Stanton, F. M. Clark	33° 49′	118° 00′	12.80
19	Buena Park, Nelson	33° 52′	118° 00′	16.00
17	La Habra, Packing House	33° 56′	117° 57′	16.84
4	Garden Grove, H. A. Lake	33° 46′	117° 57′	14.16
3	Garden Grove, Allen Bros.	33° 47′	117° 56′	14.71
11	Anaheim, Water Department	33° 50′	117° 55′	16.67
33	Fullerton, O. V. Knowlton	33° 52′	117° 54′	18.49
23	Newport Harbor, U. S. W. B.	33° 36′	117° 53′	13.80
28	Dyer, Holly Sugar Corporation	33° 43′	117° 51′	14.08
42	Santa Ana, S. Hill and Son	33° 45′	117° 52′	16.81
34	Orange, Samuel Armour	33° 47′	117° 51′	15.54
12	Olive, K. V. Wolff	33° 50′	117° 51′	18.16
41	Santa Ana, U. S. W. B.	33° 46′	117° 50′	18.67
51	5 miles west of Irvine, Irvine Ranch Company	33° 39′	117° 51′	15.22
13	Villa Park, J. F. Allen	33° 48′	117° 50′	17.20
14	Yorba Linda, U. S. W. B.	33° 53′	117° 49′	18.72
27	Tustin, High School, U. S. W. B.c	33° 44′	117° 49′	14.79
24	Tustin, Cent. Lemon Association	33° 45′	117° 49′	15.72
1	El Modena, Hewes Ranch	33° 47′	117° 49′	18.43
50	Myford, Irvine Ranch Company	33° 44′	117° 47′	14 07
49	Irvine, Irvine Ranch Company	33° 41′	117° 46′	14.97
35	Irvine, San Joaquin Fruit Company	33° 43′	117° 46′	15.26
136	Pomona, U. S. W. B.	34° 04′	117° 46′	24.76
137	Claremont, U. S. W. B.	34° 06′	117° 43′	------
129	Chino, American Beet Sugar Company, Plant	34° 01′	117° 42′	24.80
130	Chino, American Beet Sugar Company, East Camp	34° 00′	117° 40′	23.16
101	Ontario, Southern Pacific R. R.	34° 03′	117° 39′	20.19
100	Ontario, High School	34° 01′	117° 38′	20.27
114	Upland, Ontario Power Company	34° 05′	117° 39′	25.16
131	Upland, J. R. Johnson	34° 09′	117° 39′	27.42
150	Alta Loma, Ontario Power Company	34° 07′	117° 37′	29.45
107	Alta Loma, L. A. Smith	34° 07′	117° 36′	26.98
108	Guasti, Guasti Wine Company	34° 04′	117° 35′	20.45
141	Corona, U. S. W. B.	33° 52′	117° 35′	17.26
144	Corona, Temescal Water Company	33° 52′	117° 34′	17.65
106	Cucamonga, H. H. Thomas	34° 06′	117° 34′	22.10
127	Norco, Corona Heights Water Company	33° 57′	117° 33′	14.55
103	Wineville, Stern and Company	34° 01′	117° 31′	18.23
105	Etiwanda, Walter Barnes	34° 08′	117° 31′	22.77
149	Glen Ivy, Temescal Water Company	33° 46′	117° 29′	23.77
120	Fontana, Southern California Edison Company, Lytle Creek, U. S. W. B.	34° 12′	117° 27′	39.44
104	Fontana, Fontana Farms Company	34° 06′	117° 26	21.75
147	Riverside, U. S. W. B.	33° 58′	117° 26′	14.14
124	Devore, R. B. Peters	34° 14′	117° 25′	37.98
121	Fontana, Southern California Edison Company	34° 09′	117° 24′	23.65
142	Fontana, U. S. W. B.B	34° 06′	117° 25′	24 22
145	San Bernardino, U. S. W. B.	34° 06′	117° 17′	20.55
110	Highland, Mrs. C. L. Fraser	34° 08′	117° 13′	21.47
109	Highland, Thomas Ewing	34° 08′	117° 12′	23.38
146	Redlands, U. S. W. B.	34° 04′	117° 12′	19.50
119	Mentone, Southern California Edison Company, Santa Ana P. H. No. 3	34° 07′	117° 06′	25 70
115	Mentone, Southern California Edison Company, Mill Creek No. 2, U. S. W. B.	34° 05′	117° 03′	27 95
148	Beaumont, U. S. W. B.	33° 56′	117° 00′	27.75

B Station 142, position by latitude and longitude as given by U. S. W. B. corrected. Location, northeast corner Palmette and Foothill boulevard.

C Station No. 27, is sheltered from east to west.



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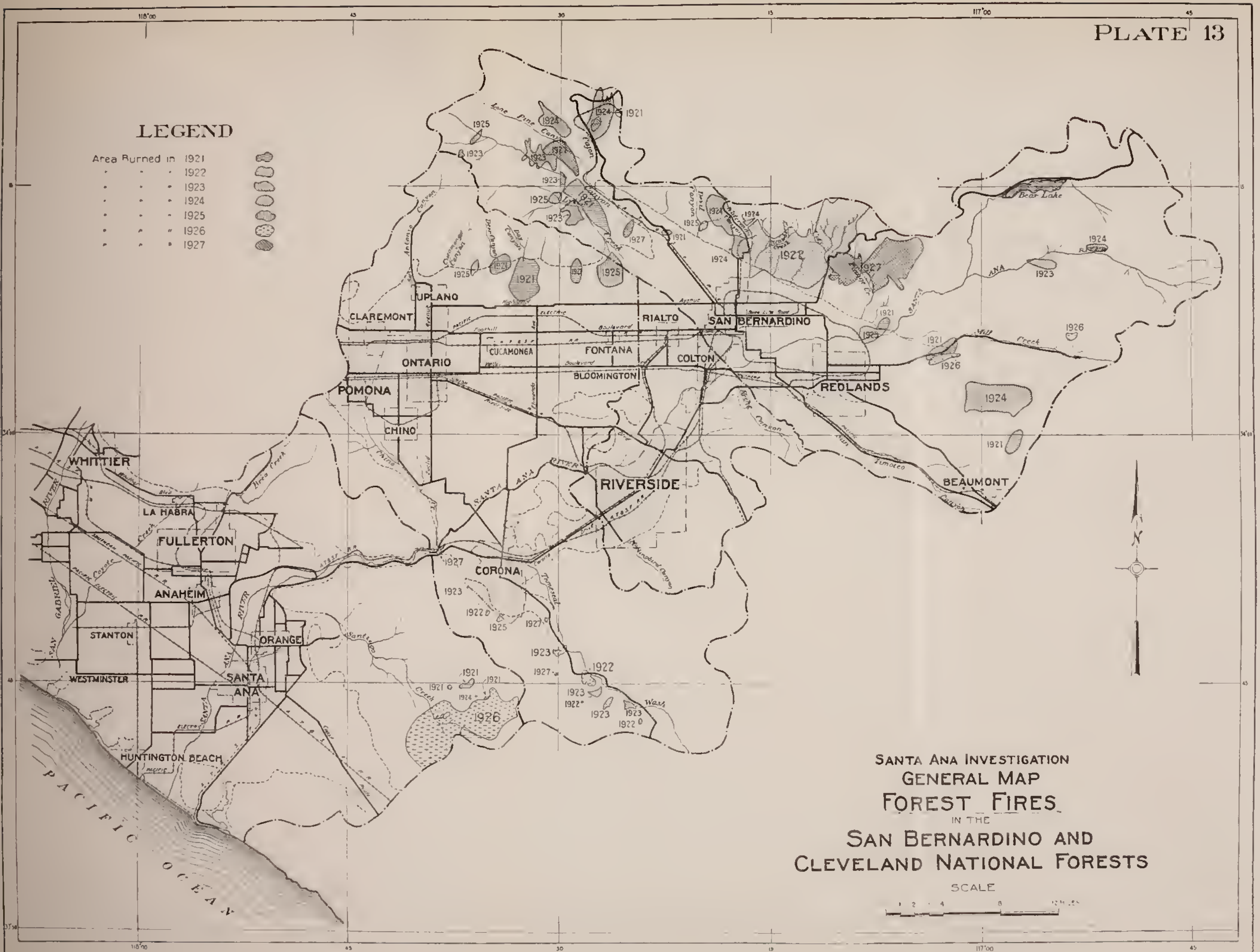
PLATE 13
LEGEND
Area Burned in 1921
1922
1923
1924
1925
1926
1927
SANTA ANA INVESTIGATION
GENERAL MAP
FOREST FIRES
IN THE
SAN BERNARDINO AND
CLEVELAND NATIONAL FORESTS
SCALE
UPLAND
CLAREMONT
ONTARIO
CUCAMONGA
FONTANA
RIALTO
SAN BERNARDINO
COLTON
BLOOMINGTON
REDLANDS
POMONA
CHINO
RIVERSIDE
BEAUMONT
WHITTIER
LA HABRA
FULLERTON
ANAHEIM
CORONA
ORANGE
STANTON
WESTMINSTER
SANTA ANA
HUNTINGTON BEACH
PACIFIC OCEAN
Bear Lake
SANTA ANA RIVER

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CHAPTER 11

FOREST FIRES AND THEIR EFFECT ON FLOOD FLOWS

By courtesy of the U. S. Department of Agriculture, the following information regarding major fires in the San Bernardino and Cleveland National Forests is published. These are shown graphically on Plate 13, facing page 222.

TABLE 48. FOREST FIRES IN UPPER SANTA ANA WATERSHED, SAN BERNARDINO NATIONAL FOREST

Streams	Year	Acres burned	Streams	Year	Acres burned
Little San Gorgonio	1921	910	Potato Canyon	1924	4,120
Mill Creek	1921	1,640	Devils Canyon	1924	2,450
Santa Ana River	1921	400	Arrowhead Springs	1924	680
Lytle Creek	1921	2,000	Cajon Creek	1924	2,000
San Sevaine Creek	1921	700	Waterman Canyon	1924	70
Day Canyon	1921	3,040	Cajon Creek	1924	1,040
Deer Canyon	1921	1,200	Coon Creek	1925	350
City and Strawberry Creeks	1922	18,230	Devils Canyon	1925	150
Barsley Creek	1923	1,185	Lytle Creek, South Fork	1925	500
Polly Butte Fire	1923	300	Lytle Creek	1925	1,920
Santa Ana River	1923	700	Foothill, North of Alta Loma	1925	225
Santa Ana River	1923	800	Baldy Fire	1925	80
Summit Valley Fire	1923	1,500	Falls Creek	1926	175
Cajon Creek	1923	160	Mill Creek	1926	240
Lytle Creek, North Fork	1923	1,000	Plunge Creek	1927	8,800
Lytle Creek, North Fork	1923	140	Cajon Creek, Glen Elen Ranch Fire	1927	160
Lytle Creek	1923	800	Lone Pine Creek	1927	1,768
Santa Ana River	1924	150			

TABLE 48. FOREST FIRES IN LOWER SANTA ANA WATERSHED, CLEVELAND NATIONAL FOREST

Stream	Year	Acres burned	Stream	Year	Acres burned
Santiago Creek	1921	55	Temescal Creek	1923	160
Silverado Canyon	1921	244	Williams Canyon	1923	8
Gypsum Canyon	1922	9	Indian Canyon	1923	200
Mayhew Canyon	1922	450	Williams Canyon	1924	1
Indian Canyon	1922	2	Eagle Canyon	1925	100
Temescal Creek	1922	35	Santiago Creek	1927	12,000
Santiago Creek	1923	65	Bedford Canyon	1927	30
Tin Mine Canyon	1923	1	Anderson Canyon	1927	9
Bixby Canyon	1923	74	Santa Ana Lower Canyon	1927	12
Horsethief Canyon	1923	160			

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CHAPTER 11

FOREST FIRES AND THEIR EFFECT ON FLOOD FLOWS

By courtesy of the U. S. Department of Agriculture, the following information regarding major fires in the San Bernardino and Cleveland National Forests is published. These are shown graphically on Plate 13, facing page 222.

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Santa Ana River	1921	400	Arrowhead Springs	1924	680
Lytle Creek	1921	2,000	Cajon Creek	1924	2,000
San Sevaine Creek	1921	700	Waterman Canyon	1924	70
Day Canyon	1921	3,040	Cajon Creek	1924	1,040
Deer Canyon	1921	1,200	Coon Creek	1925	350
City and Strawberry Creeks	1922	18,230	Devils Canyon	1925	150
Barsley Creek	1923	1,185	Lytle Creek, South Fork	1925	500
Polly Butte Fire	1923	300	Lytle Creek	1925	1,920
Santa Ana River	1923	700	Foothill, North of Alta Loma	1925	225
Santa Ana River	1923	800	Baldy Fire	1925	80
Summit Valley Fire	1923	1,500	Falls Creek	1926	175
Cajon Creek	1923	160	Mill Creek	1926	240
Lytle Creek, North Fork	1923	1,000	Plunge Creek	1927	8,800
Lytle Creek, North Fork	1923	140	Cajon Creek, Glen Elen Ranch Fire	1927	160
Lytle Creek	1923	800	Lone Pine Creek	1927	1,768
Santa Ana River	1924	150			

TABLE 48. FOREST FIRES IN LOWER SANTA ANA WATERSHED, CLEVELAND NATIONAL FOREST

Stream	Year	Acres burned	Stream	Year	Acres burned
Santiago Creek	1921	55	Temescal Creek	1923	160
Silverado Canyon	1921	244	Williams Canyon	1923	8
Gypsum Canyon	1922	9	Indian Canyon	1923	200
Mayhew Canyon	1922	450	Williams Canyon	1924	1
Indian Canyon	1922	2	Eagle Canyon	1925	100
Temescal Creek	1922	35	Santiago Creek	1927	12,000
Santiago Creek	1923	65	Bedford Canyon	1927	30
Tin Mine Canyon	1923	1	Anderson Canyon	1927	9
Bixby Canyon	1923	74	Santa Ana Lower Canyon	1927	12
Horsethief Canyon	1923	160			

INTENSIVE STUDY OF RUN-OFF OF A BURNED-OFF AREA*

This study is made of a small, steep mountain canyon, 177 acres in extent, adjoining Devil's Canyon in the San Bernardino mountains. It was burned over on August 31, 1925. In 1927 the California Forest Experiment Station, in cooperation with San Bernardino Water Department and other agencies, erected numerous rain gages and chronograph registers on this area, and built an impounding reservoir called Barranca Reservoir, immediately below.

The mean slope of the area is approximately 2½ feet horizontal to 1 foot vertical.

The record consists of the storms of February and April, 1928. It was decided to use the chronograph showing stages of water in Barranca Reservoir alone for purposes of determining the inflow. The reservoir, according to this chronograph, has a seepage or absorption which must be considered in accounting for the water. The following table shows the calculated results:

	For 177 acres, second-feet	*Run-off per square mile, second-feet*
Peak February 4, 1928	3.50	12.60
Average February 4, 1928	0.15	.50
Average April 3	0.05	.18

On Devil's Canyon the U. S. G. S. discharge shows:

	For 6.3 square miles, second-feet	*Run-off per square mile, second-feet*
Peak February 4, 1928	49.0	8.0
Average February 4, 1928	16.0	2.5

The amount of debris transported by the storm of February 4, 1928, was 1726 cubic feet. The corresponding amount of water and debris as measured was 13,040 cubic feet. The percentage of solids was 13.2 per cent.

The amount of debris transported by the storm of April 3, 1928, was 1210 cubic feet. The amount of water and debris as measured was 4168 cubic feet, making the percentage of solids 29 per cent. The quantity of solids carried for the season was 17 per cent of the total run-off.

During the rainy season of 1927–28 there were only two "effective" storms, *i. e.*, storms of sufficient intensity to produce measurable run-off at the canyon mouth, and to deposit erosion-debris in the reservoir. That of February 3 and 4 brought a total rainfall of 3.35 inches over Barranca watershed in 31 hours and deposited most of the coarse-grained debris; that of April 3 brought a rainfall of 1.42 inches. The maximum rainfall intensity was one-half inch in one hour, between 7 and 8 a. m., February 4, and the maximum run-off rate lagged but 15 minutes behind this surge of the storm. This rapid concentration of run-off waters reflects the following conditions of the watershed: Steep slopes, much bare rock and hard subsoil, scant vegetation, no vegetative litter on the steep soil surfaces, well defined drainage gullies formed by previous storms since the fire, and disturbance of exposed soil by animals and wind.

*By C. J. Kraebel, California Forest Experiment Station.

CHAPTER 12

HISTORIC GEOLOGY RELATING TO THE ABSORPTIVE SEDIMENTARY FORMATIONS

It is considered that the nonabsorptive granites and the semiabsorptive shales and sandstones were formed either before or during the Tertiary period of the geologic ages.

The end of the Tertiary period ushered in the Pliocene period, marked in Southern California as a period of depression when the lands of the region were covered by the sea, and the troughs of the prior existing valleys became filled with sediments.

The Quaternary period followed with the Sierran Epoch of long duration when the coast was elevated several thousand feet above its present position. At this time the principal terracing along the coast took place, and the channel islands were connected with the mainland. This was the glacial period in the Sierras when the great canyons were carved out by ice, and when undoubtedly the major valley of Southern California and the Santa Clara Valley had deep canyons that extended far beyond the present shore line before reaching the sea. On account of the coastal uplift and canyon cutting, this period was one of no marine sediments.

Next came the San Pedro Epoch, an epoch of depression during which the coast lowered from 300 to 700 feet below present elevations. The valleys were inundated, the shore line of the ocean encroached upon the land, and the preexisting valleys became filled with gravels and other fluviatile sediments. Some of these same sediments probably occupy the troughs of the present existing valleys at their greater depths.

The Terrace Epoch then followed with an uplift along the coast; surface streams reappeared and the sediments of the San Pedro Epoch were nearly all eroded. During this epoch, most of the existing terraces in the fluviatile sediments of the coastal and the interior valleys were formed. The Terrace Epoch marked the close of the Quaternary Period.

The latest geological epoch is known as the Recent Epoch, characterized by a general subsidence of the land to its present stage. The major part of the existing valley fills was deposited during this subsidence. A large proportion of these sediments was laid down under water. Of late years the shore line has been fairly constant, the movements of the coast being such that the sea has, only at times, inundated the lower reaches of the valleys.

Formation of Alluvial Cones and Fans. Detrital cones have been formed since the recession of the sea. The weathering action of the elements has caused the mountain streams, even those of small drainage areas, to form their own distinctive cones or fans. Characteristic examples may be seen along the northern rim of the Cucamonga Basin. These typical fans were forming in the San Pedro Epoch. Their confluence underlies the present surface of the valley floor. When the entire valley floor was inundated by the sea, the stream borne detritus was, as now, deposited at the mouths of the canyons, but then the material fell into a body of water and assumed a form quite different than that now seen in the deposits on the dry slopes of the valley.

Alluvial fans and detrital cones from the streams are built up by lenticular masses of clay, sand, gravel, and boulders brought down from the mountains by successive floods. The character of the material from a stream varies with the intensity and duration of its flood. In general the coarser materials such as boulders and gravel are deposited near the canyon mouth, and as the stream continues out over the valley with decreasing velocity the finer material is deposited, the silt being carried in suspension to the greater distances. As the years go by, the apex of the cone is built up higher and higher and the fan spreads out, the beds of the channels are continually raised until the stream, overflowing its bank, starts a new course down the fan crossing, recrossing, and flooding the other channels. This criss-crossing of channels and flooding of old channels occurs at various places, and under varying conditions, with the result that the older channels become filled with different kinds of sediments. In some places the channel is filled with porous gravels while adjoining may be a fill of impervious clay. This crossing and mingling of channels and lenses occurs in both horizontal and vertical directions as the cone builds up. It follows that all these old channels or lenses have or have had a common source in the apex of the cone at the mouth of the canyon.

The deposition of these cones under water results in a slightly different formation. The streams that debouch directly into a body of water have their velocity checked in a manner different than those that flow down the sides of a cone. Under water there is a mechanical separation of the material. The currents caused by the discharge of these streams into the general body of water, together with the tides of that body of water, if any, spread the various sediments out in different directions, in more or less horizontally stratified layers for many miles around the mouth of the canyon. This results in a confluence and intermingling of the sediments of the various streams debouching into the same body of water. In the subaqueous deposition of sediments the apex of the cone has not the extended relation to its cone as does the apex of a cone that is deposited on land.

The alluvial sediments which are tributary to the Santa Ana watershed have been divided into three groups, the Upper, Middle, and the Lower basins.

The Upper Basin contains those sediments which lie to the east of the Lytle Creek-San Jacinto Fault which is commonly known as the Bunker Hill Dyke. In this area are included the present detrital cones of Lytle Creek, Cajon Creek, Santa Ana River, Mill Creek, San Timoteo Canyon, and numerous intermediate streams. The surface waters from these streams all combine and pass over the Bunker Hill Dyke in the main channel of the Santa Ana River.

The Middle Basin occupies that territory tributary to the Santa Ana River between the Bunker Hill Dyke and Rincon. Passing over the Bunker Hill Barrier, the Santa Ana River winds along the southern edge of the Cucamonga Valley among the granitic hills near Riverside, and at a distance of about 25 miles from the Upper Basin, it enters the narrows between the Puente hills and the Santa Ana mountains. Above this entrance to the Santa Ana Canyon flows also the drainage from the south out of Temescal Canyon, and from the north out of Chino Creek. Also tributary to the Middle Basin are the waters and sediments of the streams bordering the foothills along the northern slope of Cucamonga Valley between San Antonio and San Sevaine Creeks, as well as the lateral run-off from the hills to the south of the Santa Ana River.

The Lower Basin commences at Rincon where the Santa Ana River starts on its course through the hills for a distance of about 15 miles, finally emerging upon the Downey Plain. The Lower Basin contains the Downey Plain and its extension beyond the Dominguez Ridge into Moneta Plain. Several large streams also make contribution to the Downey Basin beside the Santa Ana River. To the south of the Santa Ana River the Santiago Creek flows westward from the Santa Ana mountains and contributes its sediments and waters. To the northwest of the Santa Ana River the Rio Honda and San Gabriel River debouch upon the Downey Plain a distance of about 10 miles away. These streams have cut transversely across the divide connecting the Puente hills and the Los Angeles hills. At a distance of about 10 miles to the northwest of the San Gabriel River, the Los Angeles River and the Arroyo Seco flow through the gap in the Los Angeles hills and add their depositions onto the Downey Plain.

Geologic Classification. Under the present scheme of analysis the geologic formations as noted on the general geologic map of the Santa Ana watershed are classified into three groups, the absorptive, semiabsorptive, and the nonabsorptive formations. This classification shows the relation between the geologic formation and its suitability for the absorption and retention of water that finds contact with it either through direct rainfall or by percolation.

The nonabsorptive areas represent those areas which are elevated in position and are composed for the most part of hard compact resistent masses of igneous rocks, chiefly granites in the area under discussion. These nonabsorptive rocks extend below the general surface topography and may underlie the other classified areas at shallow depths. These areas are exposed to the heaviest rainfall, and except where they are locally shattered, shed without absorption the rain that falls upon them.

The semiabsorptive areas are composed in general of sedimentary deposits laid down in deep waters during the Tertiary period. These sediments are mostly sandstones and shales. Originally they were horizontally stratified but since their deposition under waters they have been tilted, broken, faulted, metamorphosed, and their interstices have become filled with cementing material that holds them together. The exposed layers of clay and siliceous shales have a tendency to deflect the passage of waters that come in contact with them on the surface, and to stop the passage of waters that come in contact with them underground. The sandstones are generally porous but their fine pores do not act as do porous gravels with the result that the waters coming in contact with them are very slowly absorbed, and conversely the sandstones are very slow in yielding their water to artificial draft. Most of the coarse sediments that accompany these sandstones have been cemented together to form impervious conglomerates. In this group of semiabsorptive material are also included certain areas of unconsolidated sediments whose present positions are elevated beyond their natural source of replenishment, or else are so isolated that if water were applied to them they would not constitute a storage basin and could not maintain the water table at a height sufficient for economic extraction.

The absorptive areas are of recent geologic deposition and have been formed by the cones and fans of the various streams or else are the result of general erosion and weathering upon the flat lands and the adjoining slopes. These absorptive sediments have been deposited both on dry land and under water. It is in such sediments as these that we look for storage basins because they are not consolidated or cemented and for the most part are loose and spongy and their positions occupy the lower parts of the valleys and underlie the irrigable areas where water can be maintained in storage at depths compatable with economic extraction. The absorptive areas embrace the alluvial valleys which are the field of agricultural activities and are the areas upon which this investigation of underground water conservation has been centered.

In the period that elapsed during the accumulation of the absorptive sediments the coast was successively raised and lowered many hundreds of feet both above and below its present level. The waters of the ocean successively invaded and receded from the main portions of the valleys. Contemporaneously with these changes the weathering action on watersheds and the stream transportation were continually bringing down detritus to the mouths of the canyons sometimes depositing it directly into the sea, and sometimes forming detrital cones along the slopes of the basins. As these sequences followed each other, the gradient of the floor of the major valley of Southern California kept changing as well as the courses of the streams that meandered across it on their way to the ocean. The older semiabsorptive sediments were instrumental in the deflection of these stream channels.

During the deposition of these later sediments the main outlet of the Santa Ana River shifted its channel over the floor of the valley. At one time it seems to have run along the northern edge of Cucamonga Valley, skirting the foothills, and finding its exit to the sea either to the north of the San Jose hills or between the San Jose hills and the Puente hills, continuing down through the Paso de Bartolo. Such meanderings by the Santa Ana River and other large streams during periods of degradation caused these streams to scour out channels in the older sediments in order to maintain a gradient on their way to the sea. This process left the valley dissected by many channels with terraces and floor planes along their banks, quite comparable with those on the present surface topography. Following this sequence of degradation, came a period of aggregation which is continuing to the present time. The older terraces and channels, especially in the Cucamonga and San Bernardino Valley, are being covered by new deposits from detrital cones and fans with extensive deposits of coarse gravel.

Upper Basin. The Upper Basin of absorptive sediments is wedge-shaped in appearance with a southwest-northwest trend. It is bounded on the east by the San Andreas Fault, which skirts the foothills of the San Bernardino Plateau. The Bunker Hill Dyke marks the western boundary, and forms the dividing line between the San Bernardino and the Cucamonga valleys. The northwestern end of the basin terminates in the arms of alluvium which extends up Lytle and El Cajon canyons. The southeastern limit of the basin is determined by the pass which separates Yucaipa from Banning and which connects the San Jacinto range with the Beaumont bench. The Upper Basin is divided physiographically into two divisions by the Crafton hills; one the San Bernardino Valley on the north, and the other, Yucaipa Valley on the south.

Yucaipa Valley consists principally of deposits of old alluvium forming a mesa with little tributary drainage. Consequently, the land is of much higher elevation than is the San Bernardino Valley, because there is little action from stream degradation. The mesa is cut by numerous ravines which find their way westward into the sands of the badlands, and eventually emerge into the San Timoteo Canyon. These badlands, which form the western boundary of Yucaipa Valley, are impervious in their makeup, and form an efficient barrier along the southwestern border of the Yucaipa ground water basin.

Crafton hills form the divide separating the Yucaipa Valley from the San Bernardino Valley. The hills run at right angles to the general trend of the basin. Within the hills are two exposures of granite separated by about a mile and a half of old alluvium. In all probabilities the granite is continuous under the ridge. The eastern end of the hills disappear under the alluvium, leaving a gap of about a half mile near the mouth of Mill Creek which is covered with the old alluvium connecting the two main valleys. This gap seems to be composed of a part of Mill Creek cone.

The southwestern extension of Crafton hills merges into the Badlands range. The granite outcrop disappears about a mile northeast of San Timoteo Canyon.

The later alluvium of Yucaipa Valley is merely a veneer of residual soil resulting from weathering of the underlying older alluvium, and wells penetrating water zones receive their supply from the older formation of alluvium.

The San Bernardino Valley may be considered as a single basin. It is bounded on three sides by granitic bedrock while the fourth side is merely a structural feature of the alluvium where there seems to be an unconformity in the movement of the ground waters as they percolate onward in their general movement toward the ocean. Along the eastern edge of the basin, skirting the foothills is the San Andreas Fault which is still subject to occasional movements. This is one of the major faults in California, and the fault scarp is traceable along the hills beyond the limits of our alluvial basin. The Lytle Creek San Jacinto Fault seems to lie in about the same position as the western boundary of the San Bernardino Basin. It may be coincident with the so-called Bunker Hill Dyke. This fault probably appears in the bedrock underlying the alluvial sediments, but it is very doubtful if there is any appreciable effect of it in the overlying alluvium. The general trend of these two faults is the same, being northwest and southeast. Several other faults have been attributed to this basin, having much the same trend as the two above mentioned ones, but they are more or less hypothetical and have grown out of the unexplainable behavior of certain deep wells within the basin.

The undulations in the granitic bedrock account for many of the smaller subbasins within this area. There appears to be a granitic ridge traversing the basin in a general northwest-southeast direction. The northwestern part of this ridge appears on the surface in many places, and tends to be a continuation of the ridge dividing Lytle Creek and Cajon Canyon. To the southeast the ridge disappears under the alluvium in the neighborhood of Santa Ana wash, but outcrops again on the Crafton hills. Several of the deep wells along the Santa Ana wash and vicinity have encountered bedrock which is undoubtedly an extension of this ridge. The composition of this ridge is mainly a granitic schist. These granitic spurs are more profuse at greater depths than they appear on the present surface and they determine the course of the movements of the ground waters in many localities. If the absorptive sediments could be stripped from the granitic bedrock, the present streams would undoubtedly meander over the basin in entirely different courses than they do at present.

The alluvial sediments have filled the basin in the past to even a greater height than they appear at present. During the recent epoch these older sediments have been eroded and in places have become deeply buried by the later alluvium. In certain localities, especially along the margin of the basin where stream action has not been very severe, there still remain remnants of this older alluvium perched up like benches. These older sediments should be continuous beneath the later alluvium of the basin, but in places where the bedrock is close to the surface the deep cutting and scouring of the major stream channels may have eroded them entirely.

The older alluvium was very probably washed into the basin when the whole valley was inundated by waters from the ocean, so that the deposition as a whole is somewhat the same. The various streams had their cones as they do now, but there was more interconnection between the various cones, with considerable clay material dispersed throughout the whole deposit. With the elevation of the land during the present epoch, and the driving out of the ocean waters, much of this old alluvium is perched along the margin of the valley. Except where the present channels of the streams pass over these older sediments, these elevated benches are not situated so as to receive much replenishment from the surface waters. They are, however, subject to the percolation of underground waters. The older alluvium which exists beneath the major part of the basin serves as a fine aquifer. Water that runs down stream channels penetrates the later alluvium and finds its way into the underlying sediments, becoming distributed over the basin as a whole. This is more true near the apices of the cones, because at the upper end of the cone the lenses of gravel converge, and there is better access for the water in the channel to penetrate the mass, while at the lower end of the cones, surface water is very apt to rest upon the layers of clay and not get access to the deeper lenses of gravel that radiate out from the apices.

The later alluvium is more homogeneous and spongy, being composed of unconsolidated sands, gravels, and clays, and generally absorbs the surface waters more readily than does the older alluvium.

Middle Basin. The Middle Basin is marked by several subdivisions which are caused by the protrudance of the granitic bedrock. This granitic area extends along the southern part of the basin from Colton to Corona, and in reality is a part of the bedrock forming the southern end of the basin. In an effort to straighten out its alignment between Colton and the Santa Ana Canyon below Corona, the river has cut its channel through this granitic area during the recent epoch, and, being the main drainage of the basin, occupies the lowest position. All other surface streams, as well as the underground waters, find their way either into the channel of the Santa Ana River or toward the general outlet at Prado.

The Cucamonga Valley comprises that part of the Middle Basin lying south of the San Gabriel Range and to the north of the Jurupa Mountains. It constitutes the largest unit of absorptive sediments in the basin. On the east it is separated from the upper basin by the Bunker Hill Dyke. Geologically speaking, the Cucamonga Valley and the San Bernardino Valley are contiguous, both being the result of the main drainage system of which the Santa Ana River has been the largest factor. At the present time, the Santa Ana River does not meander over the Cucamonga Valley. During the formation of the older alluvium, the river probably ran to the north of the Jurupa Mountains, and had its outlet from the middle basin in the passes west and north of Pomona. During the recent epoch, when the later alluvium was being formed, the Santa Ana River has shifted to the south of the Jurupa Mountains, and has not been instrumental in the degradation of the sediments of the Cucamonga Valley.

The sediments in the Cucamonga Valley are not all of local origin. The older alluvium which underlies the basin is contemporaneous with the older alluvium of the Upper Basin. Skirting the foot of the San Gabriel Mountains are numerous deposits which are similar in color and composition to those deposits which flank the foothills of the Upper Basin. Similar deposits are also found along the Highgrove Bench to the south of the Santa Ana River in the Middle Basin. The contributing streams, which carried down these deposits of old alluvia, traversed granitic mountains and thus their residual deposits were similar in character and composition. The Puente Hills, which form the western boundary of the Cucamonga Valley, are composed mainly of soft, light-colored sandstones, and the residual soils and sediments derived from this source, both during the formation of the older alluvium and at the present time, are governed by the characteristics of the formations found in the hills. During the formation of the older alluvium, Lytle Creek and Cajon Canyon were important factors in the contribution of sediments to Cucamonga Valley. The contours of the alluvial cones from these streams still predominate on the western side of Bunker Hill Dyke.

During the elevation of the country which followed the deposition of the older alluvium, the meandering of the streams across the Cucamonga Valley eroded considerable of the sediments that had been previously laid down. The meandering of these streams, chief of which was the Santa Ana River, left escarpments and terraces such as are seen upon the floor of any large valley at the present time. The erosion from the hills to the north of the basin became effective when the courses of the streams in the Upper Basin found their way to the south of Jurupa Mountains, and the depressions and escarpments of Cucamonga

Valley became covered over by the detrital cones from the San Antonio, Cucamonga, Deer, Day, Etiwanda, and San Sevaine canyons. These streams all present typical alluvial fans along the foothills of the valley, and the deposits are composed of later alluvium.

Remnants of the old alluvium can still be seen in a few places in the valley, especially conspicuous being Red Hill and Indian Hill.

The later alluvium covers the greater part of the Cucamonga Valley. In many places this deposition of soil and gravel is merely a veneer, and has little depth. Along the northern foothills the detrital cones extend south about as far as Base Line, while Cucamonga and San Antonio cones reach a little farther. The two latter streams are about the only ones which have contributed any appreciable amount of detritus to the lower part of the basin. The lower part of the basin is covered by soils and sediments which have resulted from a general weathering of the older underlying alluvium and occasional washes from the excessive floods of neighboring streams. Many miles of the lower lands are covered with wind-blown sand, which has been blown down the valley off of the detrital cones, as the severe windstorms sweep over the country from Rialto toward Chino.

The Chino Basin is a local designation for the southwestern portion of the Cucamonga Valley. Until recent developments around the upper portions of the cones, this basin was the depository for the detrital material carried down by the floods of San Antonio and Cucamonga creeks. Recent construction of check dams and diversions from the streams control the waters of these streams so that there is seldom a flood that reaches the Chino Basin. For about two miles north of the Santa Ana River, between Jurupa Mountains and the Puente hills, there is a strip of land which seems to be a remnant of the old alluvium. It has been protected from erosion by the presence of Jurupa Mountain on the east. It is very likely, also, that granite underlies parts of this area in close proximity to the surface, which would also protect the erosion of the overlying formations. Much of the old alluvium north of Rincon is residuum from the soft, white sandstone formations that compose the Puente Hills.

The Highgrove Bench constitutes that part of the Middle Basin lying south of the Santa Ana River which is composed of alluvial deposits. This area extends from Highgrove south to Arlington. These deposits of soil and sediment are a part of the old alluvium, having the characteristic reddish yellow appearance.

The Corona Basin is another unit that belongs to the Middle Basin. It constitutes the lower part of Elsinore Valley, including the alluvial deposits north of Lake Elsinore and lying south of the Santa Ana River. This area is covered, for the most part, by old alluvium which was derived from the granites and washed down Elsinore Valley in times past. The present divide in the valley comes at Elsinore, and the drainage to the north passes along Temescal Creek until it joins the Santa Ana River near Corona. Most of the alluvial deposits lie to the west of the Temescal Creek. In the vicinity of Auburndale are some of the light colored deposits lying on the mesa between the Santa Ana River and Temescal wash. These sediments are derived from the same source as those around the Chino Basin.

Lower Basin. The Lower Basin is considered as commencing at the head of the Santa Ana Narrows. After cutting through the soft sandstone hills for about eight miles, the river gradually broadens out on to the Downey Plain. In this vicinity we encounter remnants of the old alluvium which were laid down at an earlier geologic period.

The Downey Plain is a trough of sedimentary deposits about 12 miles wide and about 36 miles long, with its axis in a general northwest and southeast direction. Its northeasterly side is bounded by the Santa Monica Mountains, the Puente Hills, and the Santa Ana Mountains. Its southwesterly side is bounded by the Dominguez ridge and the Laguna Hills. Into this trough several other streams also debouch, chief of which, besides the Santa Ana, are the San Gabriel, the Los Angeles, the Rio Hondo, and the Santiago streams. Each of these streams has had a large share in times past in filling up the trough of the Downey Plain.

The sediments in the Lower Basin are divided into two divisions corresponding to the older and later alluvium that is found in the Middle and Upper basins. Most of the remnants of the older alluvium are lying along the edge of the foothills on the eastern edge of the basin.

There is considerable variance among the geologists of the oil fields as to the age of the sediments overlying the Dominguez Ridge. In some places the first thousand feet of alluvium seems to be flat, while in other places the alluvium has taken on the general dip of the underlying anticline of the ridge. It seems very probable that these overlying sediments are a part of the old alluvium and that their structure is due to the gradual folding of the underlying formations of shale and sandstone. The old alluvium rests along the foothills on the eastern side of the basin at an elevation of about 400 feet above sea level. This indicates that these particular sediments were at least 400 feet lower when the basin was below the sea level and the sediments were laid down. At the same time, the Dominguez Ridge must have been about the same amount lower than its present position, and we would infer that a similar depth of alluvium was laid down on top of the existing structure. Of course, the extent of erosion of the original anticlinal structure would determine the depth of submergence and the possible depth of material that could be deposited during the deposition of the sediments comprising the old alluvium. The sediments overlying the Dominguez Ridge are a long way from their source in the San Bernardino Mountains. The material that has been borne down by the stream has had a chance to settle down in the Upper and Middle basins, and as the suspended material finally reached the Lower Basin, most of the coarse material had been deposited or else had been worked down by abrasive action in the course of its journey. Emerging from the Santa Ana Canyon, the coarser material settled down at the apex of the cone of the Lower Basin. The remaining material was carried westward and deposited along the Dominguez Ridge or even in the area now occupied by the Moneta Plain. The sediments overlying the Dominguez Ridge are thus composed of silts and tight material, in comparison to the depositions along the apex of the cone near the foothills. The presence of the structure of the ridge was influential, at least, until the sediments had reached the top, and under this condition the ridge would be flanked and partially built up by the silts, while the coarser material would remain behind in the trough of the basin as the velocity of the water was checked and unable to bear its load.

The nature of the sedimentation and the structural movement of Dominguez Ridge have brought about a reaction against the percolation of the ground waters, similar to the resistance to the movement to ground waters that is caused by the semiabsorptive sediments. For this reason the areal geology of the ridge classifies the sediments as belonging to the semiabsorptive sediments.

La Habra Valley is a subbasin that is separated from the Downey Basin by a ridge similar in structure to Dominguez Ridge. The Santa Ana River may have had its course through this valley at some stage, and the deposition of old alluvium along the foothills may have been influenced by this stream to a great extent. Near the mouth of the Santa Ana River the gravels of the old alluvium are coarse, but in the neighborhood of Whittier and Santa Fe Springs the alluvium gives way to clays with little gravel. Erosive action in the La Habra Valley has been slow in comparison to the degradation done by the Santa Ana River and the other large streams, so that there is at present little residual material in the form of later alluvium.

The sediments in the main trough of the Downey Basin are probably about 1200 feet thick, below which would be found the thick beds of clay, shale, and other formations, belonging to the semiabsorptive group, and which would act as the bottom of the basin. Along the main axis of the trough the later alluvium probably constitutes about half of this thickness, and toward the eastern and western rims of the basin the later alluvium becomes less, until it disappears. There is little doubt but that the older alluvium was deposited when the ocean covered the coastal region. The formation is more or less stratified with sheets of clay deposits that extend laterally and dip down under the deposits of the trough. The stratified sediments all have their source or apex at the mouths of the various stream channels that have entered the basin, but as the coastal region undulated, the mouths of these streams extended and receded from their present locations.

The later alluvium is now occupying portions of the trough where the older sediments have been scoured out. During the refilling by these later sediments, the coast line has been undulating to such an extent that the ocean has intermittently covered the Downey Plain and then receded. This situation is revealed by the various horizons in the well logs that show the presence of shells which must have been deposited under water or at least under estuarine conditions. These later sediments are more open than the deeper ones; the layers of clay are more oxidized, and are broken up by the channels of streams that have meandered across the plain to the ocean. The depths of the deposits of clays, sands, and silts are not as thick as are found in the older alluvium, while the gravel deposits are more lenticular, giving a more homogeneous deposit. The upper part of the later alluvium is composed of coarse sands and fine gravel at the mouths of the canyons entering the basin, but this soon gives way to the finer sands and silts as the distance from the mouths of the canyons increases.

NOTE.—Certain sections shown on Plates 16, 17, 18, and 19, herewith, of this Bulletin also appear in Bulletin 17, "The Coordinated Plan of Water Development in Southern California," Div. of E. & I., Dept. of Public Works. In some cases the lettered designation is different. Identical sections are designated in the two bulletins as follows:

In Bulletin 19 Geologic Section	Plate Number		*In Bulletin 17* Geologic Section
A—A	16	equals	A—A
C—C	17	equals	C—C
G—G	17	equals	F—F
E—E	18	equals	D—D
F—F	16	equals	E—E
H—H	18	equals	L—L
K—K	19	equals	P—P
L—L	19	equals	Q—Q

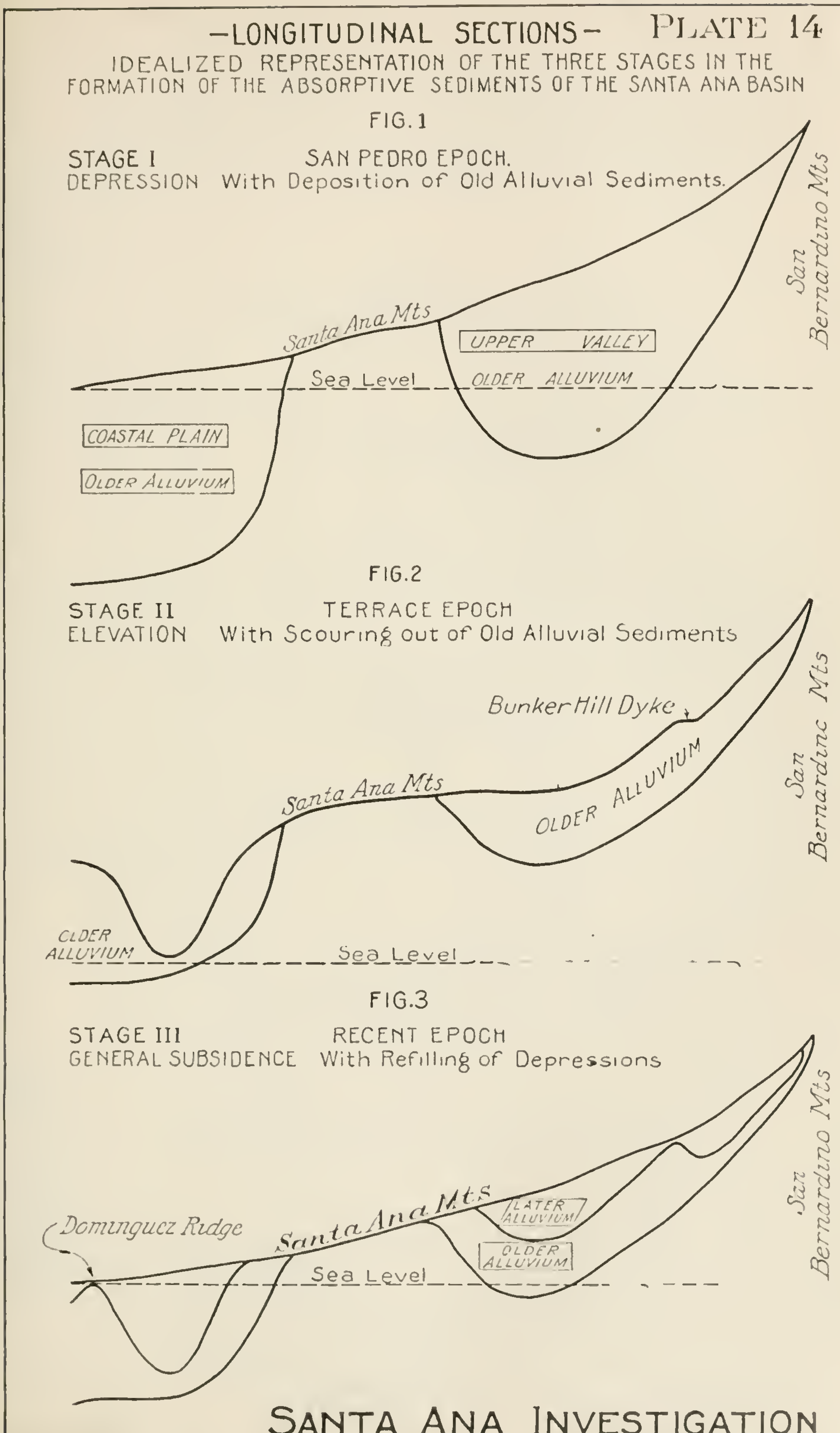

—LONGITUDINAL SECTIONS— PLATE 14
IDEALIZED REPRESENTATION OF THE THREE STAGES IN THE FORMATION OF THE ABSORPTIVE SEDIMENTS OF THE SANTA ANA BASIN
FIG. 1
STAGE I SAN PEDRO EPOCH.
DEPRESSION With Deposition of Old Alluvial Sediments.
San Bernardino Mts
Santa Ana Mts
UPPER VALLEY
Sea Level
OLDER ALLUVIUM
COASTAL PLAIN
OLDER ALLUVIUM
FIG. 2
STAGE II TERRACE EPOCH
ELEVATION With Scouring out of Old Alluvial Sediments
Bunker Hill Dyke
San Bernardino Mts
Santa Ana Mts
OLDER ALLUVIUM
OLDER ALLUVIUM
Sea Level
FIG. 3
STAGE III RECENT EPOCH
GENERAL SUBSIDENCE With Refilling of Depressions
San Bernardino Mts
Santa Ana Mts
LATER ALLUVIUM
Dominguez Ridge
OLDER ALLUVIUM
Sea Level
SANTA ANA INVESTIGATION

PLATE 15

SANTA ANA INVESTIGATION

– TRANSVERSE SECTIONS –

IDEALIZED REPRESENTATION OF THE THREE STAGES IN THE FORMATION OF THE ABSORPTIVE SEDIMENTS OF THE SANTA ANA BASIN.

FIG. 4.

SECTION ACROSS UPPER VALLEY.
SAN BERNARDINO MOUNTAINS IN LOW RELIEF.

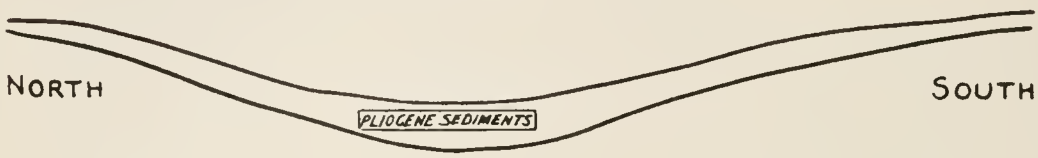


FIG. 5.

A PERIOD OF DEPRESSION
SAN BERNARDINO MOUNTAINS 2000 FEET LOWER THAN AT PRESENT

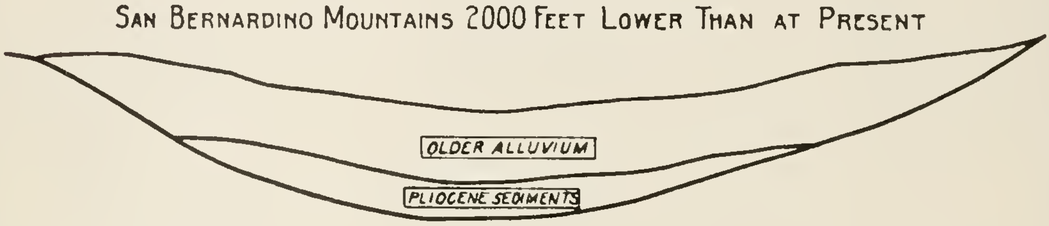


FIG. 6.

A PERIOD OF ELEVATION
SAN BERNARDINO MOUNTAINS ELEVATED TO THEIR PRESENT POSITION

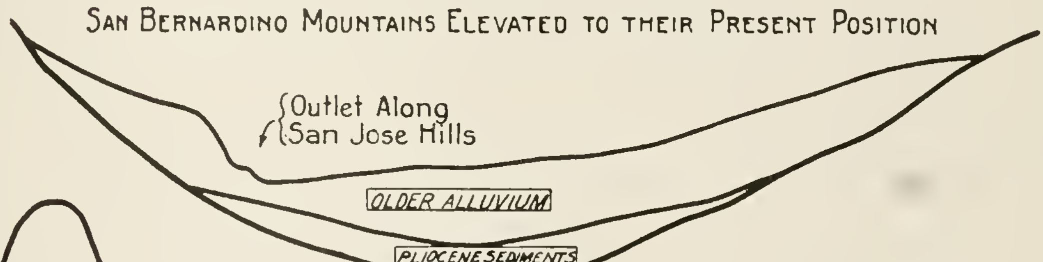
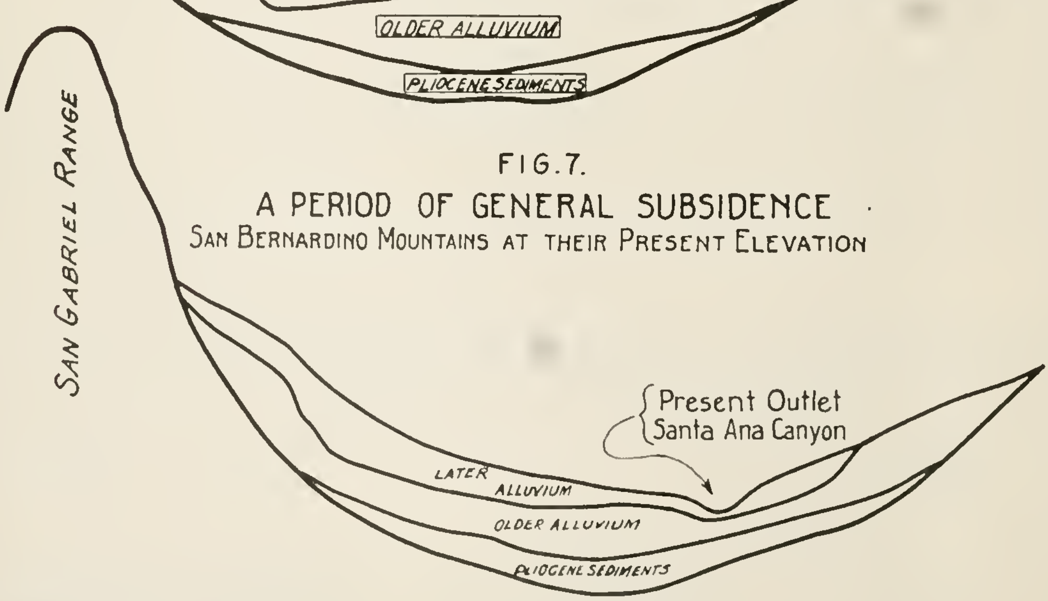


FIG. 7.

A PERIOD OF GENERAL SUBSIDENCE
SAN BERNARDINO MOUNTAINS AT THEIR PRESENT ELEVATION



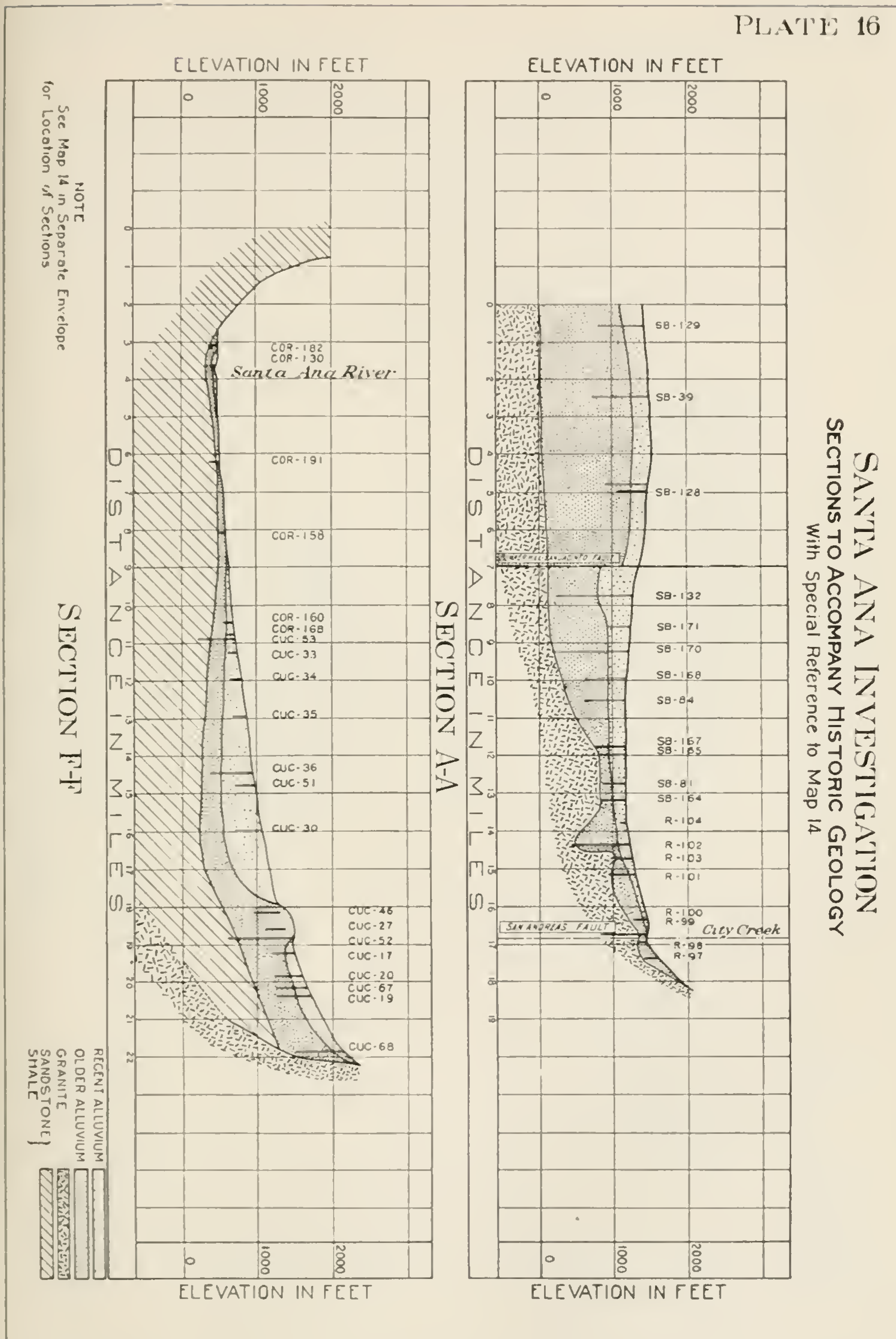


PLATE 16
SANTA ANA INVESTIGATION
SECTIONS TO ACCOMPANY HISTORIC GEOLOGY
With Special Reference to Map 14
SECTION A-A
SECTION F-F
DISTANCE IN MILES
ELEVATION IN FEET
0
1000
2000
SB-129
SB-39
SB-128
SB-132
SB-171
SB-170
SB-168
SB-84
SB-167
SB-165
SB-81
SB-164
R-104
R-102
R-103
R-101
R-100
R-99
R-98
R-97
City Creek
SAN ANDREAS FAULT
COR-182
COR-130
Santa Ana River
COR-191
COR-158
COR-160
COR-168
CUC-53
CUC-33
CUC-34
CUC-35
CUC-36
CUC-51
CUC-30
CUC-46
CUC-27
CUC-52
CUC-17
CUC-20
CUC-67
CUC-19
CUC-68
NOTE
See Map 14 in Separate Envelope for Location of Sections
RECENT ALLUVIUM
OLDER ALLUVIUM
GRANITE
SANDSTONE
SHALE

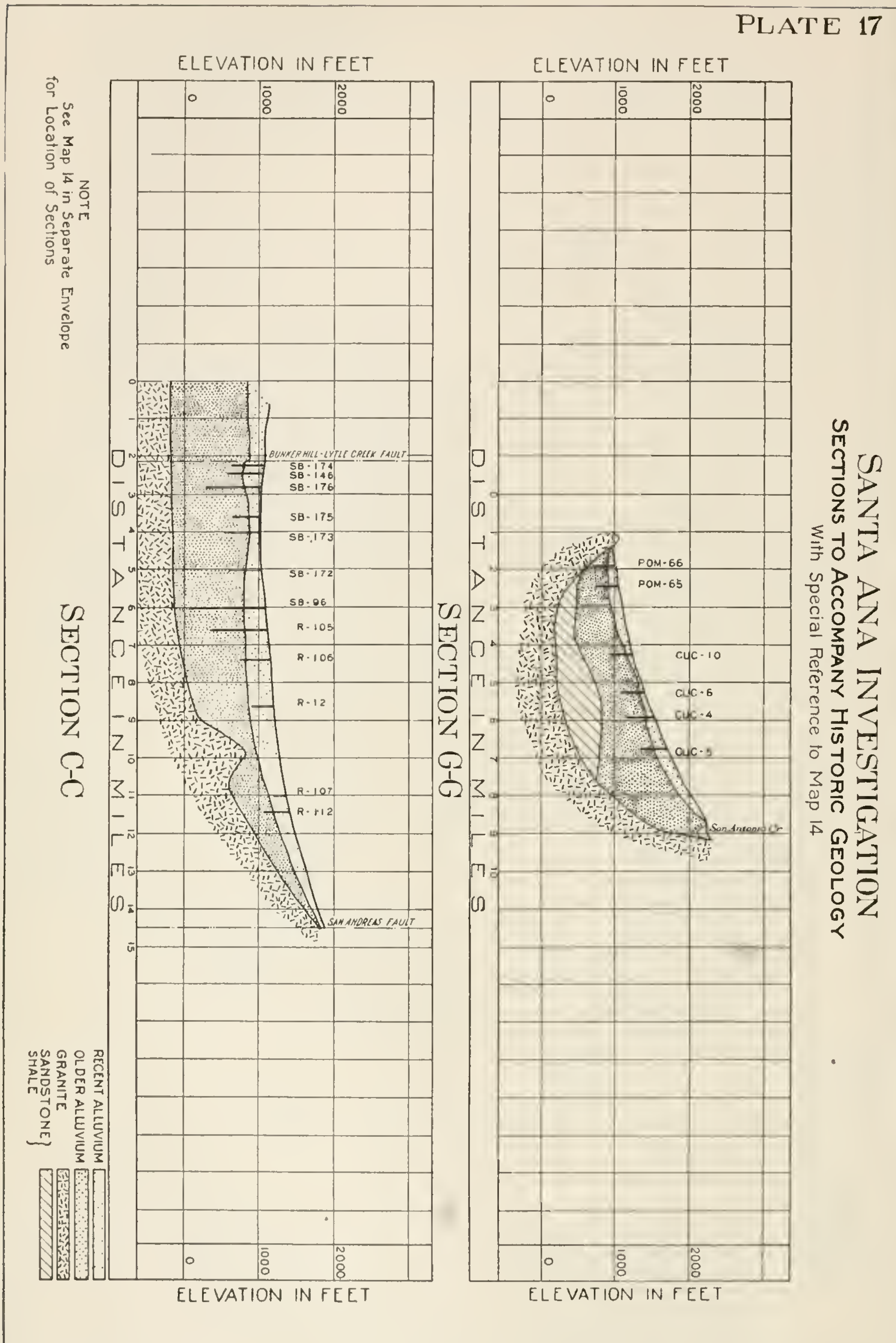


PLATE 17
SANTA ANA INVESTIGATION
SECTIONS TO ACCOMPANY HISTORIC GEOLOGY
With Special Reference to Map 14
SECTION C-C
SECTION G-G
ELEVATION IN FEET
DISTANCE IN MILES
BUNKER HILL-LYTLE CREEK FAULT
SB-174
SB-146
SB-176
SB-175
SB-173
SB-172
SB-96
R-105
R-106
R-12
R-107
R-112
SAN ANDREAS FAULT
POM-66
POM-65
CUC-10
CUC-6
CUC-4
CUC-5
San Antonio Cr.
NOTE
See Map 14 in Separate Envelope
for Location of Sections
RECENT ALLUVIUM
OLDER ALLUVIUM
GRANITE
SANDSTONE
SHALE

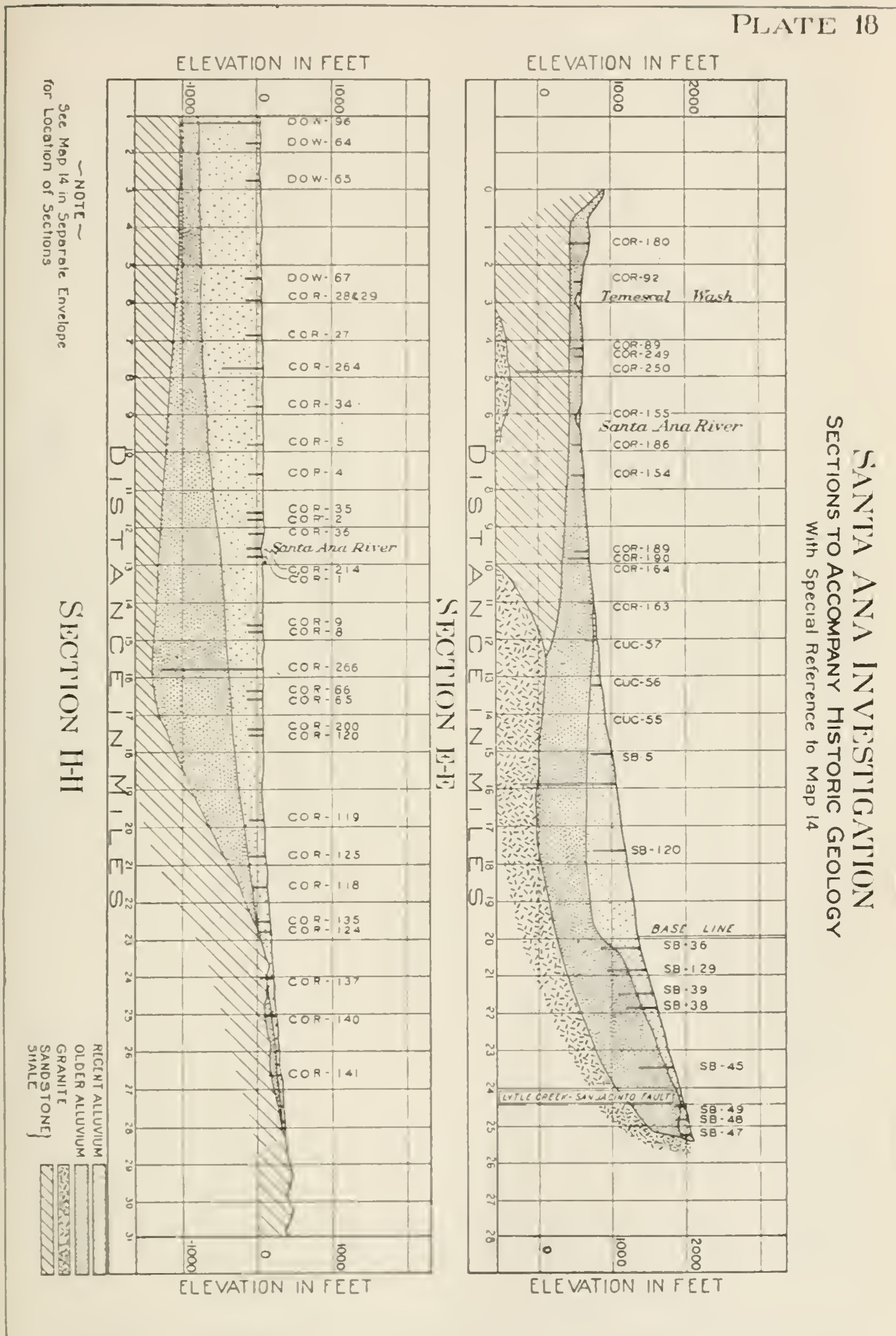


PLATE 18
SANTA ANA INVESTIGATION
SECTIONS TO ACCOMPANY HISTORIC GEOLOGY
With Special Reference to Map 14
SECTION H-H
SECTION E-E
DISTANCE IN MILES
ELEVATION IN FEET
~NOTE~
See Map 14 in Separate Envelope
for Location of Sections
RECENT ALLUVIUM
OLDER ALLUVIUM
GRANITE
SANDSTONE
SHALE
Santa Ana River
Temescal Wash
BASE LINE
LYTLE CREEK-SAN JACINTO FAULT

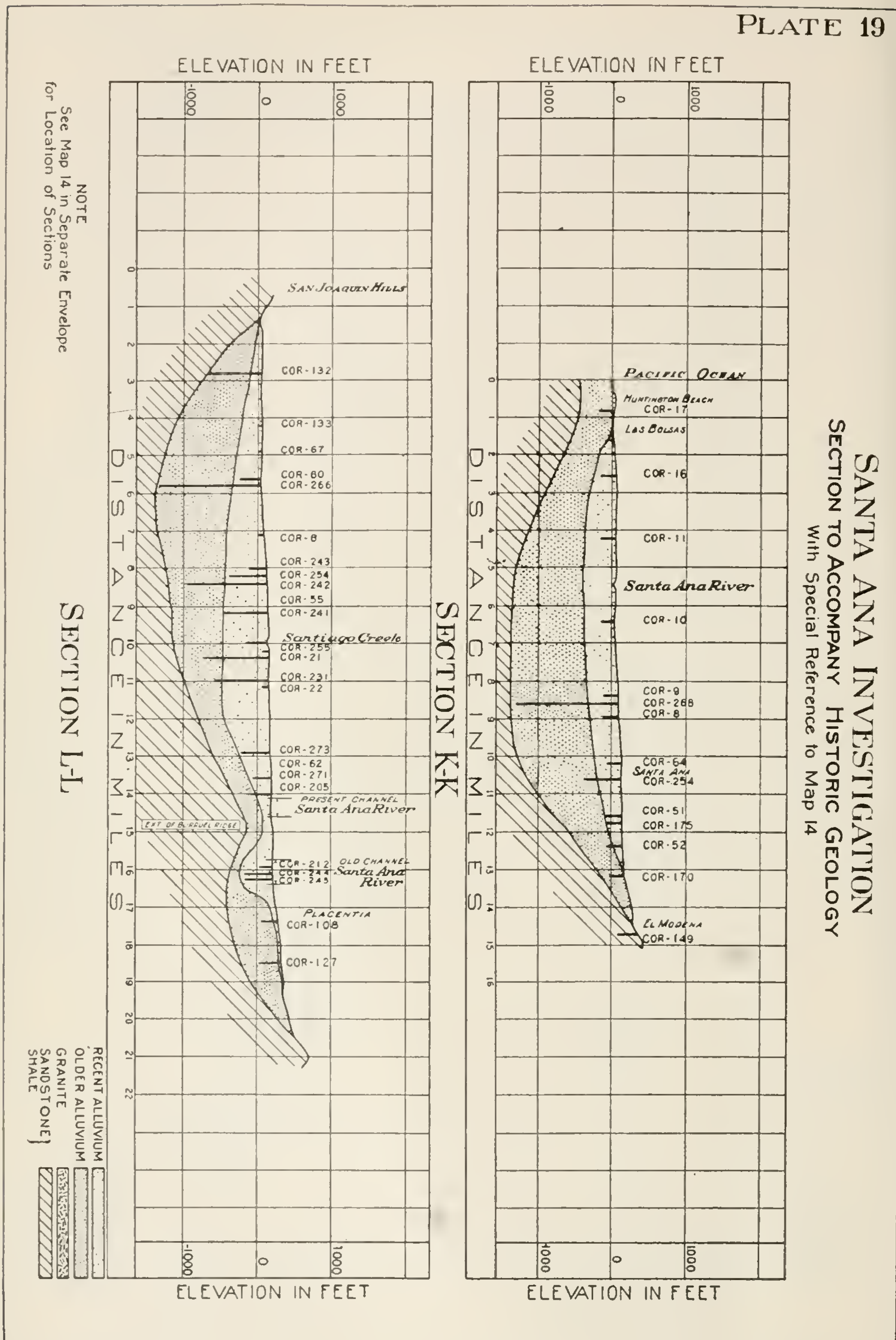


PLATE 19
SANTA ANA INVESTIGATION
SECTION TO ACCOMPANY HISTORIC GEOLOGY
With Special Reference to Map 14
SECTION K-K
SECTION L-L
ELEVATION IN FEET
DISTANCE IN MILES
Pacific Ocean
Huntington Beach
Las Bolsas
Santa Ana River
Santa Ana
El Modena
San Joaquin Hills
Santiago Creek
Present Channel
Old Channel
Placentia
NOTE
See Map 14 in Separate Envelope for Location of Sections
RECENT ALLUVIUM
OLDER ALLUVIUM
GRANITE
SANDSTONE
SHALE

GEOLOGY OF THE LOWER CANYON OF SANTA ANA RIVER WITH SPECIAL REFERENCE TO DAM CONSTRUCTION*

Object. This geologic investigation was undertaken at the request of the Division of Engineering and Irrigation of the Department of Public Works, State of California, in order to ascertain the geological conditions as related to dam construction in the lower canyon of the Santa Ana River in Orange and Riverside counties.

In this investigation, no attempt is made to discuss the engineering and economic factors which will enter into the final selection of the most suitable location for a dam, but rather the report has been confined to the presentation of the geologic considerations that must enter into such a final selection. The geological investigation was undertaken by the writer with the following clearly in mind: The geological conditions might be unfavorable for certain types of dam construction and yet be suitable for a dam of another type. The final selection will necessarily depend upon those engineering and economic factors which enter into the proper selection of all important dam sites.

Acknowledgments. The writer wishes to express his appreciation for the valuable data contributed by Mr. Chester Marliave, geologist for the State Engineer's office, who collaborated in the field, and for the many helpful suggestions received from Mr. Paul Bailey, chief engineer of the Orange County Flood Control.

Location and Extent of Area Examined. The area examined in this investigation, which is shown on the accompanying geological map, Plate 22, page 264, includes the lower canyon of the Santa Ana River, in Orange and Riverside counties.

The geology along the canyon for a distance of about 10 miles, from the upper or eastern end, to the lower or western end, and for a distance of about one mile north and south of the river, was studied and mapped.

Previous Geological Studies in the Area. The general geology of the region, including the lower canyon of the Santa Ana River, has been previously studied and described, but not in sufficient detail for the purposes of the present investigation. The best and most elaborate work previously done in the area was the investigation made by Walter A. English for the U. S. Geological Survey, the results of which were published in 1926 in U. S. Geological Survey Bulletin 768. This bulletin with its accompanying maps has been of great help in the preparation of the present report.

The writer has used the correlations and formational names, as worked out by English and others, as the basis for the detailed study of the areas surrounding the various possible dam sites.

Topography and Physiography. The topography of the area surrounding the lower canyon of the Santa Ana River has been mapped by the United States Geological Survey (Topographic Branch), and these maps have been published as the Corona and Santa Ana quadrangles. In addition to these government maps, the Division of Engineering and Irrigation, of the State of California, has recently com-

*By E. K. Soper.

pleted a more detailed topographic map, on a scale of 1000 feet to one inch, covering a zone along the Santa Ana Canyon, extending about one-fourth mile back from the river bed on each side. This topography was used as a base for the geological field work and is shown on the accompanying geological map, Plate 22.

The most striking physiographic features of the canyon are:

1. The higher hills and mountains are on the south side of the canyon.
2. Several nearly right-angle bends occur on the course of the canyon, between which the river follows a fairly straight course.
3. The river shows a remarkably uniform or constant grade throughout its course from Colton to the lower end of the canyon, a distance of about 40 miles. The grade of the stream through the canyon is the same as on the flat alluvial plains above and below the canyon.
4. The conspicuous terraces along the canyon sides, representing remnants of former river flood-plains which have been elevated by subsequent geologic uplift of the region.
5. At no point is there a conspicuous constriction of the side walls of the canyon.
6. At no point in the canyon is there a hard rock formation, or lip, which interrupts the grade of the river.

As will be explained in the following pages, the major topographic and physiographic features of the canyon have been determined by the geologic history of the region and by the geologic structure of the rocks.

Origin of the Santa Ana Canyon. During late Tertiary time, the surface of the greater part of Southern California was one of low relief. High land, which previously existed in the region, had been eroded away, so that the topography of the land was similar to that of a low rolling plain. Such a flat, featureless, eroded surface is called a peneplain. A remnant of this old Tertiary peneplain may still be seen in the vicinity of Perris, where the nearly flat surface is underlain by granite. A few low, rounded granite hills occur in this locality, and represent those places which had not been eroded down to the general level of the surrounding plain.

In late Tertiary time the drainage of the area now known as the San Bernardino Valley flowed south and west across this Perris peneplain in about the same general direction which it now follows. The Santa Ana River, which was probably the principal stream of the region then, as it is now, flowed along somewhat the same general course which it now follows across the valley. At the close of the Tertiary period the entire region of Southern California was greatly folded and faulted. The comparatively flat, eroded surface of the land was wrinkled and warped into mountain ranges. The rocks became broken and faulted in many places during this process of mountain folding. Large blocks of the land bounded by faults were pushed up, whereas adjacent blocks were depressed. The Santa Ana Mountains were upfolded at this time, probably as an accompaniment of the great movement along the Elsinore, Chino and Whittier faults. The Santa Ana Mountains, including the Puente Hills, (which form their northwestern continuation), were folded directly across the course of the Santa Ana River. The river, nevertheless, was able to maintain its course westward across the rising mountains because it was able to erode its channel bed as rapidly as the land was elevated. The river probably shifted its course somewhat north and south at the beginning of the uplift. The present channel was probably determined by the northern end of the mass of hard, resistent, igneous rock which forms the core of the Santa Ana Mountains. The present Santa Ana Canyon is located in soft sedimentary rocks at the north edge of the harder igneous mass. It is noteworthy that no other canyon cuts across these mountains except south of the southern extremity of this igneous mass.*

Such a stream, which follows a course developed earlier than the surrounding topography, is called an "antecedent stream." The Santa Ana River is one of the outstanding examples of antecedent streams in southern California. In brief, the river maintained its course during the uplift of a mountain range across its path.

Estimates of the time elapsed since the close of the Tertiary period vary from 300,000 to 1,350,000 years. Since the initiation of these great earth movements at the close of the Tertiary period there have been notable movements along the major faults on the east side of the Santa Ana Mountains. One or more of these movements temporarily dammed the drainage from the east and south and formed a large lake, extending from the vicinity of Prado southward along Temescal wash. This is shown by the presence of extensive quaternary lake beds (clay and silts) along Temescal wash, and at other localities east of the Santa Ana Mountains. However, the river succeeded in maintaining its course at a uniform grade as the Santa Ana Mountains were slowly elevated. Conspicuous evidence of the elevation of the land is seen in the numerous deposits of Quaternary terrace gravels along the canyon now high above the present level of the stream. These gravel terraces represent uncroded remnants of the old flood plain of the river which have been elevated to their present levels.

Other evidence of the antecedent character of the stream is seen in the fact that its gradient throughout the canyon is the same as it is across the flat plain above and below the canyon. In this respect the river is remarkable, maintaining, as it does, a nearly uniform grade from the Sierra Madre to the sea. Streams flowing through mountains usually develop a decided quickening of current, due to increased gradient.

General Geology and Stratigraphy. The rocks exposed at the surface along the lower canyon of the Santa Ana River are mostly sandstones, conglomerates, and shales and intermediate phases, all of comparatively recent geologic age. Older rocks occur on the hills a short distance to the south, but along the canyon the rocks range in age from Cretaceous to Quaternary, with Tertiary formations predominating. About half way between the east and west ends of the canyon, near the Orange-Riverside county line, there is a small area of brecciated igneous rock of an andesitic type, which occurs along the Whittier fault at this locality and which has probably been brought to its present position by movements along the fault in early Quaternary time. This is the only igneous rock exposed in the canyon, although large areas of igneous rock occur in the mountains a short distance south of the canyon.

*For a more detailed account of the origin and history of the Santa Ana River Canyon see U. S. G. S. Bulletin 768, p. 64-66 by Walter A. English.

The following table includes all of the formations recognized in the canyon.

Geological Formations Exposed Along Lower Canyon of Santa Ana River *

Age		*Formation*
QUATERNARY	RECENT	*Alluvium*
	PLEISTOCENE	*Terrace gravel* *San Pedro Formation.* Sandstone and conglomerate of fresh water origin. Only one area found along canyon.
TERTIARY		*Unconformity*
	PLIOCENE	*Fernando Formation.* Buff clay shale and some sandy shale with considerable sandstone and some conglomerate.
		Unconformity
	MIOCENE	*Puente Formation.* (Formerly called "Monterey Shale.") Alternating sandstones, conglomerates and shales. Shale is diatomaceous, color varies from bluish brown to light buff. Sandstones predominate in Puente at this locality. Formation is divided into four members: lower shale; middle sandstone; upper sandstone and upper shale. The sandstones are seldom hard enough to form prominent outcrops. *Unconformity* *Topango Formation.* Buff to nearly white arkosic sandstones (containing feldspar) with much interbedded conglomerate. Middle Miocene.
	OLIGOCENE	*Sespe Formation.* Red sandstone, red clay and sandy clay with interstratified greenish and buff beds, shales and sandstones. Probably includes some Vaqueros (Miocene).
		Unconformity
	EOCENE	*Martinez Formation.* Dark gray to greenish shales, containing carbonaceous beds.
CRETACEOUS		*Unconformity*
	CHICO	*Chico Formation.* Conglomerate, light colored sandstones and bluish, laminated shales. Not exposed along river but found a short distance south of canyon.

*Classification as to age and formational names taken from U. S. G. S. Bulletin 768 by Walter A. English.

The rocks exposed throughout the canyon are all soft and easily weathered. The sandstones and conglomerates are poorly cemented and frequently weather on the surface to such an extent that they crumble when squeezed in the hand. Certain strata in each formation are harder than the others, but such strata are of small thickness and are not continuous. Hardening seems to be local and due to abrupt changes in the cementing material of the rock. In general, one can not fail to be impressed by the entire absence in this area of hard, firmly cemented rocks. The shales which occupy areas as great as those occupied by sandstones and conglomerates, are easily weathered and crumble or ''slake'' when exposed to the air for a few months. For this reason they are easily eroded and consequently the shale areas usually occupy valleys and gulches. Good outcrops of shale are scarce except along roadcuts and other artificial excavations. Where shales occupy steep slopes, such as hillsides or riverbanks, landslides are common, especially where the dip of the shale is in the same direction as the slope of the surface.

Structure of the Rocks—General Structural Conditions. ''Structural geology'' is a study of the arrangement, attitude and physical condition of the rocks. The structural geology of the Santa Ana Canyon area is very complex. The rocks, mostly of Tertiary age, are greatly folded and in many places they are broken, or faulted. In places the strata, particularly the shales, are overturned and highly contorted. The complexity of structure is increased by the presence of incompetent beds (shales) interstratified with more competent formations (sandstones). The weaker and more yielding clay shales have been squeezed and bent, so that their outcrops usually show more deformation than do the more competent sandstones and conglomerates.

The general structure of the area has developed from the folding of the Santa Ana Mountains in post-Fernando time. The period of deformation is definitely fixed by the fact that the Fernando and all older formations are folded, whereas the younger Quaternary formations (San Pedro formation and terrace gravels) remain practically undisturbed, and rest upon the eroded and truncated edges of the older formations.

This post-Fernando deformation extended throughout California and much of the Great Basin region. It is generally considered as marking the close of the Tertiary period. As a result of the folding of the rocks throughout the Santa Ana Canyon, the strata are mostly tilted at considerable angles from their original horizontal position. Dips of 75 to 85 degrees are common, and in places the strata stand in a vertical position. The only horizontal undisturbed strata observed in the entire area were those of the recent post-Fernando gravels, sands, and clays (San Pedro formation) near the lower end of the canyon, particularly northeast of Horseshoe Bend Station.

Faults. A fault is a fracture, or fractured zone, in the earth's crust along which there has been slipping or displacement of the rocks. The displacement may be vertical, horizontal or at any intermediate angle. The amount of displacement (movement) of the rock on opposite sides of the fault may vary from a fraction of an inch to thousands of feet.

Movements along faults may take place suddenly, as in the case of a sudden and violent snapping or slipping of the rocks under strain, or the movements may be so slow and gradual as to be quite imperceptible. Such slow, gradual movements may, however, in the course of thousands of years amount to total displacements of great magnitude, since the effect is cumulative.

When the rocks slip suddenly along faults, earthquakes are produced. Slow, gradual movements along faults do not produce perceptible earth tremors. It has been reported that at various places where highways follow fault lines, the cost of road maintenance is higher than the average of such costs for other sections of the roads. It may be argued that even if a movement on a fault were so slow and gradual as not to be perceptible, the results of such movement would soon become visible because an escarpment, or break, would be produced at the surface. This is not necessarily true because the erosion of the land surface may proceed at such a rate as to keep pace with the fault movement and thus prevent the development of any conspicuous escarpment, or break on the surface.

Faults may be classified as "active" or "dead" according as to whether they show evidence of recent movement, or evidence that no movement has occurred for a very long period of time. Faults may also be classified according to their magnitude, as "major" or very large faults, persistent for long distances, and "local" or "minor" faults of limited length and displacement. In Southern California the active faults are generally the major faults, whereas most of the numerous, small, local faults are apparently inactive or dead.

In speaking of the time elapsed since the last movement on a fault, reference is generally made to geologic time, which is measurable in thousands rather than in hundreds of years. If a fault shows evidence of movement within historic time it should be classified as active, since there is a strong probability that the rocks may slip again along that particular line of weakness.

The rocks in the area under investigation are broken by many faults. Most of these faults are local, "dead" faults of small extent and displacement. The largest and most important faults in the area, the ones along which the greatest displacement has occurred, are the Whittier and Chino faults, both of which are branches of the Elsinore fault. The Elsinore fault is one of the major faults of Southern California. The Elsinore fault extends along the northeast base of the Santa Ana Mountains and separates the mountains from the Perris peneplain. A few miles southeast of Corona the Elsinore fault splits into two branches, the Whittier fault and the Chino fault. The Chino fault continues northwestward along the east base of the Puente Hills to the south base of the San Gabriel Mountains. The Whittier fault, from the junction with the Chino fault, curves more to the west and trends about N. 65° W. along the south flank of the Puente Hills. The Whittier fault diagonally crosses the Santa Ana Canyon west of Green River Camp, about half way between the upper and lower ends. The fault appears in the south side of the canyon about 1000 feet west of Green River Camp, follows the bed of the canyon to the northwest for a distance of about one mile, and passes out of the canyon to the northwest about 1000 feet east of the Bryan summer residence. (See Plate 22, page 264.)

The Whittier fault is of an unusual type, known as a pivot fault. Along the western half of the fault, the older rocks are on the north side, whereas along the eastern end of the fault, south of the Santa Ana River, the older rocks are on the south side. The "throw" of the fault, that is, the vertical displacement of the rocks along the fault, has thus been reversed at the two ends. This is due to the fact that the Santa Ana Mountains have been tilted to the southwest, whereas the Puente Hills, north of the Whittier fault, have not been so tilted.

The Elsinore fault, with its two northwest branches, the Whittier and Chino faults, were the controlling factors in the origin of the Santa Ana Mountains and the Puente Hills, which were uplifted and highly folded in consequence of block movement along these faults. As previously stated, this deformation occurred in post-Fernando time, at the close of the Tertiary period. Various estimates place this time from 300,000 to 1,350,000 years ago. The uplift probably continued into early Quaternary time, but could not have continued long into the Quaternary period, since San Pedro beds of early Quaternary age are found practically undisturbed west and north of Horseshoe Bend, near the west end of the Santa Ana Canyon. The uplift of a range of mountains such as the Santa Ana Mountains, implies movement of the earth's crust of considerable magnitude along the Elsinore, Whittier and Chino faults in the late Tertiary and early Quaternary time. Slight movements along certain of the major faults of Southern California, notably the San Andreas, San Jacinto, Elsinore, and Inglewood faults, have occurred within recent historical time. None of these active faults cross the area under investigation, although the Chino fault lies only about three-quarters of a mile east of the upper end of the canyon. Lines of springs, some of them hot, occur along the Elsinore fault and its branches. There is, however, no conclusive evidence of record of movement within historic time along the Whittier fault or any of the smaller local faults in the Santa Ana Canyon.

In Southern California the main differential movements of the earth's crust have occurred along certain major faults, notably the San Jacinto, Elsinore, San Gabriel and Inglewood faults.* These faults represent lines of rupture in the rocks. The great blocks of the earth's crust bounded by these fault-lines have been uplifted or depressed with reference to the adjoining blocks. This differential movement is part of the process of readjustment of equilibrium to conform with the various stresses to which the rocks are subjected. Because these major faults are the lines of weakness along which any important future movement may reasonably be expected to occur, the small local or "dead" faults of the region are not regarded as a serious menace to dam construction.

Geological Conditions Controlling Choice of Dam Sites. In selecting locations for the construction of large dams the rocks which are to serve as foundations and abutments are usually subjected to careful study. Not only is it desirable to carefully examine the rocks in the immediate vicinity of the site selected, but a study should be made of

*Wood, H. O., California Earthquakes, Seismological Society of America Bulletin, Vol. 6, 1916, pp. 76-77.

the structure of the formations for a considerable distance on all sides of the site with particular reference to the possible existence of active faults, or other structural weaknesses.

The principal geologic features which should be considered in the selection of a site for a dam are as follows:

1. *Faults.* It is dangerous to construct dams on or near faults which show any evidence of movement within recent time. In general it would be well to avoid all fault lines if possible, but it is not always possible to do this, since faults are very numerous in some localities, such as the Santa Ana Mountains and throughout Southern California. There is but little risk involved in locating a dam near a dead fault of local extent and of small displacement. But there is no justification for assuming the risk involved in building a dam on or adjacent to a major fault on which there is evidence or record of movement within historical time. Dams properly constructed may safely withstand earthquakes that emanate from fault movements close at hand if these movements are not too large, but the risk is considered too great especially for dams where population will concentrate downstream, and where other sites are available. Particular care should be taken to avoid placing a dam directly across the line of an active fault. In general, a site should be selected as far as possible from active faults.

2. *Strike and dip of strata.* Where the geological formations of the area surrounding the dam site consist of stratified (sedimentary) rocks, the most favorable position would be where the strike of the strata is across the canyon and parallel to the dam, and where the strata dip upstream at a high angle, or stand vertical. This position makes it possible to select a harder and more impervious stratum, or group of strata, which can be used for the foundation, and which would thus extend continuously across the canyon for the entire length of the dam. In this position, each stratum would act as a cut-off wall and the possibility of seepage under or around the dam would be reduced to a minimum. However, it is seldom that a place can be found where the strike of the strata is exactly parallel to the axis of the dam. If the strike of the strata is parallel or oblique to the canyon, the dam will necessarily have to be placed *across* the strata. If the strike is parallel to the canyon the bedding planes, or rock surfaces separating adjacent strata, become possible zones of seepage beneath the dam. If the strike is oblique to the canyon, the most favorable condition would be where the strata dip upstream. It is usually difficult to obtain a tight and impervious cut-off where the dam crosses numerous strata. This is especially true if the rocks are thin-bedded interstratified shales and sandstones with numerous individual strata striking parallel to the canyon and dipping downstream. Moreover, there is often a thin layer of clay or shale along the bedding planes separating different strata. If the clay becomes saturated from seeping water, it is rendered soft and ''greasy'' and if the strata lie in a tilted position they may slip along one or more of these ''greased'' surfaces with possible injury to the dam. If the rock strata lie in a horizontal or vertical position the mass will be more firm and solid with less possibility of slipping. If the strata dip at some angle between

the horizontal and vertical, the mass will not be as firm and there might be some danger of slipping along the bedding planes, especially if the strata dip steeply downstream. Where the strata are neither vertical nor horizontal the most favorable condition would be where the direction of dip is upstream. In such a position water which might enter the bedding planes beneath the reservoir, if any, would seep down the dip *away from the dam*. If the strike is parallel to the stream channel (normal or oblique to the dam) the direction of dip is of less importance, but the angle of the dip should be considered. If the strata are folded (i. e., dip in opposite directions at the two ends of the dam) the degree of dip and presence or absence of fractures are of chief importance.

3. *Type of Rock.* Wherever possible dams should be located on igneous rock—preferably upon granite—since these are generally hardest, most massive, impervious, and free from bedding planes. Igneous rocks, however, are frequently crossed by numerous joints and fissures which may permit atmospheric weathering and decay to enter deeply into the rock along such cracks. Fault gauge, or clay, may also be present along cracks in igneous rock and thus cause planes of weakness. Generally speaking, the best sedimentary rock for dam foundations is limestone. Shales and sandstones may be suitable where harder formations are not available. Naturally, the most suitable rocks do not always occur in the areas where dams are to be built, or the topographic features of the land may determine the location and eliminate the possibility of any choice of rock. Dams can be safely built upon shale or sandstone, providing the formation is not excessively fissured and faulted, and not too deeply weathered or oxidized, and provided the dam is designed properly with respect to the geologic substructure. Where the rocks are soft, concrete dams involve a greater risk than earth-fill dams.

4. *Hardness and texture.* The harder and denser (less porous) rocks are preferable to soft, loosely consolidated, porous rocks. Resistance to atmospheric decay (weathering) and to the action of water are highly desirable properties of rock for dam foundations, and these properties are largely dependent upon the texture, composition and hardness of the rock. On the other hand, where more suitable formations were not available, dams have been safely built upon rather loosely consolidated sedimentary rocks. Under such conditions proper care must be taken in designing the structure and in selecting a site where the geologic structure is favorable, and in carrying the cut-off wall well below the zone of weathering. The cut-off would have to be landed in a formation that could withstand the differential pressure at the toe of the cut-off wall.

General Geologic Conditions in Santa Ana Canyon Area with Special Reference to Dam Construction. The rocks throughout the canyon are all sedimentary with the exception of a small area of igneous formation which occurs along the Whittier fault, near the Orange-Riverside county boundary in the middle part of the canyon. These sedimentary formations consist of alternating beds of conglomerates, sandstones and shales, mostly of marine origin. They originated as sediments beneath the sea and have been subsequently elevated to their present position by crustal movements of the earth. Conclusive evidence of the marine origin of these rocks is the finding of marine fossils, such as shells and sharks' teeth in the strata exposed along the canyon.

The oldest of these rocks were formed millions of years ago; the youngest perhaps 75,000 years ago. These estimates do not, of course, include the fresh water gravels and sands on the terraces and in the bed of the Santa Ana River, which are still in process of accumulation today.

The conglomerates are poorly cemented. The sandy material surrounding the pebbles and boulders crumble easily, resulting in the rapid disintegration of the rock. The conglomerate beds in places frequently appear hard and massive, but only occasionally are they sufficiently hard to withstand a mild blow with a hammer.

The sandstones, likewise, are poorly cemented and often incoherent. They are mostly coarse-grained. Much of the sandstone was formed near an old shore line from material which had its source in an old mass of granite. The material eroded from the granite was washed down to the sea by streams and there deposited. Limey material, which commonly occurs as an important ingredient in the cementing material of sedimentary rocks, is conspicuously lacking in the rocks exposed throughout the canyon. Because of the absence of sufficient cementing material the sandstones rapidly lose their cohesion and slough to loose sand when immersed unsupported in water. A few exposures of sandstone were found where the rock was rather fine-grained and harder. At many localities the sandstone can be crumbled in the hand.

The shales, when freshly exposed, are harder than the sandstones, but weather and disintegrate rapidly to soft clay.

Because of the lack of cohesion of the grains composing all of these sedimentary rocks, they are easily eroded by running water. This fact partly explains the remarkably constant grade of the river through the canyon. There were no hard ledges or strata to dam back the stream and cause a change of gradient.

The Santa Ana River at present transports very little sand and gravel except at times of flood. The stream bed is filled with gravel and sand to depths varying from 20 to 80 feet or more. Beneath this loose gravel and sand are the loosely consolidated sedimentary rocks just described. The rocks beneath the river bed vary in kind from place to place, but are, in general, the same as those exposed in adjacent parts of the canyon walls. The river is not now deepening its channel because of the thick accumulation of sand and gravel resting upon the bed rock and thus protecting it from further erosion even in periods of flood water. The gradient of the stream is now so gradual that deposition of material is the dominant process except during short periods of flood. At such times the upper portion of the sand and gravel in the river bed to a depth of 25 or 30 feet goes into suspension and is transported downstream for a certain distance depending upon the quality and velocity of the water. New material is constantly being brought by the stream into the upper end of the canyon, and is gradually carried along, by stages, until it is transported onto the plain below. During the journey through the canyon, the pieces of rock composing the stream's load are undergoing corrasion, with the result that the material becomes finer in size of grain as it is carried along. This explains why the river bed near the head of the canyon is filled with much coarser material than in the lower part.

The loose gravel and sand composing the stream bed is more or less saturated with water throughout the year. This subsurface water is constantly flowing downsteam. During the dry months more water probably flows through the sands and gravels than flows on top of the ground. The amount of underground flow varies from place to place along the canyon, as is shown by the fact that there is noticeably more surface flow at some places than at others. Places of maximum surface flow represent either places in the channel where the bed rock is nearest the surface, and where the depth of the loose river sands and gravels is correspondingly less, or places where the width of the pervious deposits is least, or combinations of both. Whereas there is always a considerable underground flow of water through the loose sands and gravels in the river bottom, it should be clearly understood that only a comparatively small quantity of water percolates through the sandstone, shale and conglomerate which compose the bed-rock formations. This is true in spite of the fact that in many places these rocks are quite soft and porous because (1) the rocks are *relatively* impervious when compared with the overlying loose sands and gravels and (2) the strata of the bed-rock formations mostly stand tilted at a steep angle, often vertical, across the channel, thus offering the maximum resistance to percolation. In this position each stratum acts as a dam across the channel of underground flowage.

Although the rocks throughout the canyon are softer and less tightly cemented than desirable for dam construction, their structural attitude is favorable at several localities. The disadvantage due to the rock texture might be overcome by selection of a dam of the earth-fill type and by special methods of construction. There would be little danger of seepage or hydraulic pressure beneath the dam where the strata stand highly tilted and broadside across the channel, with a dip upstream or toward one of the banks. Percolation should be guarded against by a deep and carefully constructed cut-off wall. On account of the soft, porous nature of the rock, special care should be taken to properly anchor the two abutments.

As previously described, there are two major faults in the vicinity of the Santa Ana River Canyon, (1) the Whittier fault which extends southeasterly along the south flank of the Puente Hills and crosses the Santa Ana River Canyon in its middle portion, near Scully's Point, and (2) the Chino fault, which extends southeasterly along the east base of the Puente Hills and passes about three-quarters of a mile to the east of the upper end of the canyon (see Plate 22, page 264). These two faults are really the branches of the Elsinore fault. In addition to these two major faults there are numerous local "dead" faults extending in various directions throughout the area. None of these smaller dead faults are regarded as sources of danger, although care has been taken to locate and examine these in the vicinity of the dam sites considered. The major faults are regarded as dangerous and it is believed desirable to keep as far as possible from either of these, although there is no geologic evidence of any movement along the Whittier fault or any of the faults in the canyon within historic time. There is some evidence, however, of rather recent movements along the Chino fault.

The last fault movement in the canyon of which there is clear evidence was probably that which has resulted in the forming of certain terraces of Quaternary gravels. It is probable that this movement which occurred along the Whittier-Puente fault involved a total displacement of from 50 to 100 feet and occurred not less than 10,000 years ago. Moreover, it is probable that the displacement did not occur all at one time, but was gradual and cumulative.

While the Whittier fault has resulted in a considerable displacement of the strata at its east and west extremities, there has been but little vertical displacement in the vicinity of where the fault crosses the canyon. This is because of the peculiar nature of the fault, which is of the pivot or "scissors" type, in which the upthrow side is reversed at the two ends, with the central portion, or pivot, showing little displacement.

The fact that the Santa Ana River has been able to maintain its uniform and constant grade, not only across the upfolded mountains but also *across the Whittier fault*, is evidence that the movement on this fault line was slow and gradual rather than sudden and violent. If movement along the Whittier fault is now occurring it must be so slow and gradual as to be imperceptible.

Although the geological evidence indicates that there is no cause to fear any violent movement on the Whittier fault in the Santa Ana Canyon region, nevertheless it is believed undesirable to locate a dam near it because of the great concentration of population and property values on the plain below. Since faults are lines of weakness in the earth's crust, where the rocks have broken under stress, if similar stresses should occur again, the rocks would probably break or move along these same lines of weakness. Construction of a dam at such a location is taking an unnecessary risk where other sites are available.

Descriptions of Various Dam Locations. On Plate 22, page 264, dam locations are shown by black lines across the canyon. These locations, numbered 1 to 12, represent all those sites in the canyon where the topography is at all adapted to dam construction, and were selected as representing the areas for intensive geologic study. The purpose of these geological studies was to ascertain the safest site, or sites, for a dam. Descriptions of, and conclusions regarding these various locations are given in the following paragraphs:

Sites 1, 2 and 3. Locations 1, 2 and 3, in the middle part of the canyon near the Green River Auto Camp and the Anaheim diversion dam, are regarded as being too near the Whittier fault for desirable locations for a dam. These three sites are satisfactory from a topographic viewpoint, but the geologic conditions are distinctly unfavorable. Site No. 1 lies across the Whittier fault, which follows the river bed at this locality. Sites 2 and 3 are immediately adjacent to the Whittier fault, which passes near the south ends of the sites. In fact, the rocks comprising the entire area around sites 2 and 3 show unmistakable signs of crushing and shattering, which has probably resulted from old movements along the fault. Both sites 2 and 3 are within the only area of igneous rock found in the canyon. This rock is completely shattered and brecciated (broken by innumerable fracture planes). The rock, which is an andesite, lies partly on the north side and partly on the south side of the river. That part on the north side of the river has probably slid or otherwise *moved* down from the fault zone on the opposite mountainside on the south side of the river, which exhibits typical landslide topography. Moreover, brecciated andesite may be seen resting upon the river gravels in the railroad cut on the north side of the river. Because of the close proximity of sites 1, 2 and 3 to the Whittier fault, and also because of the broken character of the rock at sites 2 and 3, they are considered unsafe for dam construction.

Site 4. This location extends from a point on the north side of the river about 2000 feet north of Scully Siding to the long neck of land on the south side of the river where the state highway turns east. The north end of this site consists of alternating conglomerates and sandstones with some thin interbedded shaley layers. The sandstone is yellowish to buff in color, poorly bedded, soft and rather incoherent. The conglomerate is coarse and loosely cemented, containing rounded pebbles up to six inches in diameter. The shale is sandy and occurs as thin layers interbedded with the sandstone and conglomerate strata. The south end of this site consists of sandstone and conglomerate with interbedded shaley layers very similar to, if not identical with, the formations exposed on the north side of the river. The rocks on the south side are exposed only in a small area on the point of a long, narrow ridge extending northwest from the hills to the south into the river valley, and around which the river bed has been deflected in a broad curve. Except for the small area of rock exposed on its north point, this ridge or "neck" is entirely covered by Quaternary terrace gravels and recent alluvium which obscure the underlying rock formations.

The topography suggests that the river formerly flowed in a southwest direction between the River Bank Camp and the Green River Camp, and passes south of the point of this ridge. If this is true, there would be an old erosion channel between the north end of the ridge and the edge of the hills on the south, which is now filled with river alluvium. Such a channel would be a serious obstacle to the construction of a dam at the site. The existence or nonexistence of such a filled channel could be definitely determined by core drilling.

Site 5. The topography at site 4 is strongly suggestive of a fault at this locality, as shown on Plate 22. The occurrence of the isolated hill of rock at the north end of the neck of land also indicates faulting.

The north side of the canyon at site 5 consists of dark bluish-gray clay-shale, somewhat diatomaceous, dipping steeply to the northeast at an angle of about 68°. The strike of the strata varies from N. 70° W. to N. 80° W. The shale, which is of Upper Puente age, weathers easily to a yellowish or buff colored clay. It contains considerable gypsum, which occurs as thin discontinuous seams along the bedding-planes. A noteworthy characteristic of the shale at this locality is the fact that although when freshly uncovered it is fairly hard and free from fractures, it develops innumerable intersecting, curved fractures within a few days after exposure to the air. In the course of a few weeks of exposure to the air it crumbles or slakes to a mass of small fragments. The fresh shale, in places, is impervious to water as shown by the fact that cores of the material obtained in a bore-hole beneath the river bed were quite dry. Samples, when immersed in water, showed no tendency to decrepitate. High banks composed of the shale are exposed on the north of the Santa Fe railroad tracks at this locality where the rock has been quarried by steam shovel for brick manufacture. The face of the cliff shows considerable sliding and movement, but this is in large part due to heavy blasting in connection with excavating operations. The weathered shale, when wet by the rains, forms a sticky clay which may cause landslides where the slopes are steep.

The shale is conformably overlain by a coarse, pebbly gray sandstone. The contact between the sandstone and shale is exposed on the hill near Chester siding. This contact strikes southeast across the river and passes up the gulch east of River Bank Camp.

The formation at the southeast end of site 5 consists of coarse arkosic sandstone interstratified with conglomerate beds, and some thin beds of fine, shaley sandstone. This sandy formation underlies the shale member described in the preceding paragraph. The contact between the shale and this lower sandstone-conglomerate member lies beneath the river bed at the north end of site 5, but is exposed in the first small gulch southwest of River Bank Camp (see Plate 22). A dam built at site 5 would necessarily cross this shale-sandstone (or conglomerate) contact at some point near the middle of the river channel.

Such a contact beneath the dam would be a zone of possible seepage which should be avoided if possible. Since this contact would not be encountered at site 6, which immediately adjoins site 5 on the northeast, it is believed that site 6 is the more desirable of the two.

Site 6. The north end of site 6 coincides with that of site 5 and is located in the shale near Chester siding on the north bank of the river where the river course bends from south to west. The description of the conditions at the north end of site 5, given in the paragraphs immediately preceding, will also apply to the north end of site 6, and therefore need not be repeated here. At the southeast end of site 6 the rock consists of the same shale as at its north end. The shale formation extends continuously across the river channel (although concealed by river sediments in the bed of the stream) and outcrops on the south bank of the river in the point of the hill just south of River Bank camp. The shale at this point has a strike of about N. 50° W. The dip is 80 degrees to the northeast. The shale beds cross the river approximately normal to its course and stand almost on end, with a dip of from 75° to 80° *upstream*. The strike of the shale and overlying sandstone bends to the south on the southeast side of the river. Thus it would be possible to locate a dam at this site so that the dam would be underlain by the shale throughout its entire length. The dam would be nearly parallel to the strike of the shale strata. The latter would lie in such a position (i. e., broadside to the river, with a steep dip upstream) that each stratum would act somewhat as a natural cut-off wall. The Puente-Whittier fault passes about 9000 feet to the south of the southeast end of this site.

There are three rather serious disadvantages to this site. (1) The topography of the shale hill on the north bank of the river indicates that small landslides have occurred there within recent years. This may be in part due to recent blasting, but since the shale quickly weathers to clay and slips easily when exposed on steep slopes, in case this site is selected it would be desirable to excavate the north bank until the slope of the surface is reduced to the angle of repose corresponding to that of the weathered wet shale. The abutments of any dam built on site 6 should be anchored far into the shale on both sides of the river in order to get as far as possible beyond the zone of weathering and fracture. (2) The peculiar character of the shale which causes it to crack and crumble soon after it is exposed to the air. (3) The topographic relation along the west bank of the river just west of the northwest end of site 6, and along the large arroyo, immediately east of River Bank Camp, on the east side of the river, strongly suggest the existence of an east-west fault. By reference to the map it will be seen that this arroyo, to the east of site 6, and the conspicuously straight east-west course of the north bank of the river just west of site 6, are almost exactly in line with each other. Furthermore the two series of terrace gravels which cap the hills on the north and south sides of the arroyo, while composed of similar material, are at greatly different elevations. The terrace gravels on the south side of the arroyo are 50 to 100 feet higher than those on the north side of the arroyo. Further evidence of the existence of such a fault is seen in the change of direction of strike of the formations on the east side of the river. If a fault exists along the line indicated (and direct proof of its existence is not obtainable at the surface), it would pass directly under site 6.

Test borings to a depth of 150 feet below the river bed are being conducted at this site as this report is written. (See Plate T, page 74.) The depth of sand and gravel in the river bed (depth to bed rock) varies from 50 to 82 feet. Final decision as to the geological suitability of the site will necessarily depend upon the results of these borings. Hole No. 6 (see Plate 22) showed shattered, or broken shale. Since the location of hole No. 6 is on the projection of a line of probable faulting, the finding of broken shale in this hole is an additional evidence of the existence of such a fault.

Site 7. Site 7, known as the Prado site, has been studied by others previous to the present investigation. The rock at the west end of this site consists of medium hard, gray, thin-bedded sandstone with interstratified layers of dark gray shaley sandstone. The formation has a strike of 80° W. and dips to the northwest at an angle of from 75° to 80°. The texture and composition of the sandstone varies from coarse to fine within short distances and the individual strata, which are never more than 18 inches thick, show considerable differences of hardness. The shaley phase of the formation is the hardest, although none of it could properly be described as hard. The topography of the surface at the west end of the site consists of steep, smooth, grass-covered slopes. The sandstone weathers to a dark soil and does not form bold outcropping ledges on the west side of the river as it does at places in the old river bank on the east side.

The formation at the east end of this site consists of the same series of sandstones as those which occur at the west end. The strike of the strata is approximately the same on both sides of the river, and the rock strata extends across the river approximately normal to its course.

The angle and direction of dip is approximately the same (75° to 80° N. E.) on both sides of the river. The texture of the rock is different on the two ends of the site because the two ends are not on the same stratum or group of strata. This is due to the fact that the axis of the proposed dam is not parallel to the strike of the strata, but crosses the strike of the strata on an acute angle. Therefore the rocks which outcrop at the east end of the site do not represent the same strata as those at the west end. The sandstones at the east end contain some thin conglomeratic beds and are coarser and softer than the sandstone strata at the west end. Samples of all the various textural phases from both ends of the site were collected and examined. None of the samples consist of hard rock and all of them crumble or ''slake'' to loose sand when immersed unsupported in water for a few hours.

Plate T, page 74, shows the profile of the river at site 7, and also shows the location of and results obtained from bore-holes which were drilled to test the subsurface formations at this site. The river alluvium is about 20 feet thick on the west half of the river bottom and 70 to 80 feet thick on the east half. The bed rock formations encountered below the river-bed are the same as those which outcrop on both banks. Core samples obtained from the bore-holes indicate that beneath the river-bed the sandstone strata vary in hardness and texture as they do at the surface.

There is strong evidence of faulting along the bed of the canyon at site 7. This evidence is as follows:

(1) The topography of the west side of the canyon at this locality lines up with the straight, steep, west side of a long gulch of peculiar topographic contour on the east side of the river to the south of sites 5, 6 and 7.

(2) Borings (see Plate T) show a sudden drop of 60 feet in the river-bed, which lines up with the topographic feature mentioned under (1).

(3) Extensive Quaternary terrace gravels on the east side of the river at site 7, are found at approximately the same elevation as are similar terrace gravels several miles to the northeast on the east side of the Chino fault. These terrace gravels are entirely missing on the west side of the river at site 7.

The Chino fault passes 2500 to 3000 feet to the northeast of the site. This fault is of major magnitude, and there is evidence of recent movement along it. Therefore any dam located in the upper end of the canyon would be in a possible earthquake zone, should future slipping occur along the Chino fault.

There would also be some danger of landslides at site 7, due to the fact that the sandstone sloughs to loose sand when wet. If there should be considerable recession of the water level in the reservoir, the saturated sandstone sidewalls might tend to slough and slide in. This might be the cause of considerable difficulty in obtaining a secure tie-in of the dam abutments.

Sites 8 and 9. Because of the almost identical character of the geological conditions at these two localities, they are here discussed together.

The formation around the north ends of these sites consists of sandstones and conglomerates, with a few thin shaley beds. These rocks are overlain by a covering of Quaternary terrace gravels. The bed-rock at the north ends of the sites is covered by the terrace gravels everywhere except for a few scattered outcrops near the mouths of the two arroyos north of the railroad.

Beneath the terrace gravels, the sandstone and conglomerate beds dip to the south at angles varying between 40° and 60°. The strike of the strata is about N. 70° W. North of the railroad, beneath the terrace gravels, the dip of the sandstone strata probably steepens considerably.

At the south end of sites 8 and 9 the same soft sandstone formations outcrop as are found north of the river, but with the addition of an overlying shale member. The shale-sandstone contact lies approximately along the line of the highway. The shale occurs mostly south of the highway and the sandstone to the north, between the highway and the river. The rocks dip in various directions and at various angles due to faulting and folding.

The sandstone which is well exposed in the river cliffs below the highway at this locality is soft and crumbly, and contains very little cementing material. Some of the strata are so incoherent that samples can not be obtained because the rock crumbles to loose sand when broken out of the bank. All of the sandstone here rapidly slakes or crumbles to loose sand when immersed in water.

Two small faults occur between the south ends of sites 8 and 9. The larger of these faults crosses the highway at the south end of site 9 and trends about N. 50° E., crossing the line of site 8 in the river-bed below the high embankment. This faulted condition of the formation explains its broken and crushed appearance. The faulting, together with undercutting of the high vertical embankment by the river, has resulted in a series of landslides, which have occurred immediately west of the south end of site 9.

Four bore-holes were drilled in the river-bed along the axis of site 8, to test the formation below the river alluvium. The locations of these bore-holes are shown on Plate U, page 75. The records of formations encountered in these bore-holes are given in the table at the end of this report.

No cores could be obtained from any of the holes due to the softness of the rock and lack of cohesion of the sand grains composing it. The average depth of the river alluvium is about 70 feet in the river bottom.

The faulted and crushed condition of the rock, and the occurrence of landslides on the south bank of the river at this locality, and also the very soft, incoherent nature of the sandstone which constitutes the bed-rock formation, all indicate that these sites are not desirable.

Site 10. The formation at the northeast end of this site is the same as that at the north ends of sites 8 and 9, described in the preceding paragraphs, and is covered by the same terrace gravels.

The rocks at the southwest end of site 10 consist of the same sandstone and overlying shale which occur at the south ends of sites 8 and 9. At site 10, however, the structural relations are much more favorable than at sites 8 and 9. The shale on the hill south of the highway at the southwest end of site 10 is harder, more massive, and of a whitish or light buff color. At this point the shale strikes about N. 65° E. and dips to the northwest at an angle of about 85°. The sandstone series which underlie the shale does not outcrop at the southwest end of site 10 because it is covered there by recent alluvium and terrace gravels. This sandstone series outcrops near the intake of the Anaheim Canal, about half way between the northeast and southwest ends of site 10, close to the west bank of the present channel of the river. At this place rather hard, brown sandstone is interbedded with soft, buff, shaly sandstone containing thin beds of sandy shale. The strike of the strata near the canal intake is N. 75° E. and the dip is about 80° northwest. The strike of the formation at this place is approximately parallel to the axis of the dam site, which is a favorable condition. The strata stand almost on end and broadside to the river.

By reference to the dip arrows around site 10, shown on Plate 22, it will be seen that the sandstone and shale strata which comprise the bedrock formation in this locality are folded into a series of nearly parallel anticlines and synclines. The axes of these folds follow approximately the broad curving trend of the river valley. Any dam which might be built on this site would cross the axis of a large syncline about 700 feet southwest of the private road which skirts the point of land at the northeast end of the site. This synclinal condition is not in itself unfavorable to dam construction provided the rock along the axis of the fold is not crushed or broken. Since the axis of the fold lies beneath the river-bed, the condition of the foundation along this fold can only be determined by core-drilling. Therefore it is strongly recommended that before any construction work is undertaken at site 10, a series of core-drill samples of the bedrock should be obtained from holes bored at close intervals along the axis of the proposed site. Churn-drill samples would be of little value here since they would not give the information desired, *i.e.*, the condition of the bedrock as to fractures, joints, and possible faults along the axis of this syncline.

The topographic conditions at site 10 on first inspection seem less favorable than at localities 8 and 9. However, careful examination of the surface conditions reveals the fact that at sites 8 and 9 the surface has been subject to landslides and slumping because of the steep unsupported slopes on the south side of the river. At site 10 there would be little danger of landslides because of the more gradual slopes, and because of the more favorable structural condition of the strata.

The Puente-Whittier fault passes about 3000 feet to the northeast of the north end of site 10. There is some topographic evidence of faulting in the vicinity of the terrace at the north end of sites 8, 9 and 10, but definite geological evidence is obscured by the heavy deposit of terrace gravels which cover the bedrock formations.

Sites 11 and 12. Sites 11 and 12 are very near each other, have their south ends identical, and the geologic conditions at both localities are quite similar. Therefore they can be conveniently described under one heading.

The north ends of sites 11 and 12 are both in an area of sandstone overlain by poorly stratified, horizontal, unconsolidated Quaternary gravels and sands. The formation beneath the gravel consists of a fine-grained, gray to buff-colored sandstone, with interbedded thin layers of shale. Certain of the sandstone strata contain numerous large, round concretions, which are particularly conspicuous in the railroad cut a few hundred feet east of Horseshoe Bend station.

At the north end of site 11, which passes near Horseshoe Bend station, the underlying sandstone exposed at the foot of the river bank strikes about N. 60° E., and dips to the northwest at an angle of about 47.° There is a small synclinal axis about 250 feet northwest of this point beyond which the sandstone dips in the opposite direction (to the southeast), but the strike remains unchanged. Still further northwest, on the edge of the hill north of the railway tracks, the strike of the sandstone is nearly north and south, and the dip is about 13° west. The abrupt changes of strike and dip of the formation within such short distances are probably due to the influence of a fault which bounds the sandstone on the north and which is well exposed in the railroad cut about 1000 feet east of Horseshoe Bend station. The north end of site 11 is about 400 feet from the fault. Site 12 is farther from this fault. Another fault probably passes beneath the river-bed in a general east-west direction, near the north ends of sites 11 and 12. Both of these faults are shown on Plate 22. There is no evidence of recent movement along either of these faults.

The north end of site 12 passes through a prominent point of land on the north bank of the river, near the point where a well was drilled for oil some years ago. At the base of the embankment, near the river level, on the nose of the point, a fine-grained, gray to buff, soft sandstone with interbedded shaley layers is well exposed. The strike of the sandstone here is not constant, but changes from S. 40° W. to S. 10° E., and the dip varies from 33° northwest to 15° southwest. Above the sandstone on the terrace above the river and also on the hills north of the railroad, only loose terrace gravels are exposed, which completely mask the underlying bedrock.

The south end of site 12 coincides with the south ends of sites 11 and 10. This locality has already been described under site 10.

Between the two ends of site 12 in the low bluff near the Anaheim irrigation canal, between the paved highway and the river, the bedrock is well exposed. Here the same soft gray sandstones and interbedded shales exhibit a constant strike, nearly west and east, parallel to the canal. The strata dip uniformly to the south at angles varying between 40° and 60°.

By reference to Plate 22 it will be seen that any dam built along sites 11 and 12 would cross the axes of three folds—a syncline near each end and an anticline in the center of the river valley—and at least one fault. The axes of these folds and faults follow approximately the trend of the river valley and since the average strike of the strata must be approximately parallel to the axes of the folds, it follows that the average strike of the strata beneath the river valley is also approximately parallel to the trend of the valley itself. The structural condition implies that the individual rock strata between the two ends of sites 11 and 12 are tilted at various angles with their edges parallel to the valley instead of broadside to it. As previously stated, such an attitude of the strata is regarded as less desirable for dam construction than where the strata stand broadside to the canyon.

Any dam built on strata in the position of those at sites 11 and 12 would have to cross very many separate strata. Since bedding planes, or planes of stratification, are sometimes planes of weakness or of seepage, this type of geological structure is not so favorable for securing an efficient cut-off.

The conditions in regard to possible faulting at sites 11 and 12 are somewhat doubtful, due to the fact that about one mile west of site 12 there is evidence of a fault trending along the river valley and striking toward sites 11 and 12. Because of the thick deposit of river alluvium which covers and obscures all the bedrock formations beneath the river valley, it will be impossible to determine whether such a fault, if it does exist, extends as far east as sites 11 and 12. Even core-drilling may fail to settle this question since the bedrock formation at sites 11 and 12 would probably be the same on both sides of any fault at this point. On the other hand, the occurrence of the same formation on both the north and south sides of the river valley at sites 11 and 12 indicates that if a fault exists beneath the valley alluvium it must be one of small *throw* and relatively small displacement, with correspondingly little danger of any future movement along it.

The Puente-Whittier fault passes about 3500 feet to the northeast of the north end of site 11, and about 4500 feet to the northeast of the north end of site 12.

Summary and Conclusions. All the possible sites in the lower canyon of the Santa Ana River exhibit one or more undesirable geological features. This is chiefly because of (1) the soft and poorly cemented nature of the rocks throughout the canyon and their lack of resistence to weathering and erosion; (2) the folded and distorted attitude of the strata at many localities in the canyon; (3) the entire absence of any continuous, hard, massive strata; and (4) the existence of numerous faults both large and small, throughout the entire area.

Notwithstanding the fact that the general geological conditions are unfavorable for certain types of dams, if the major fault lines are avoided it is believed a site may be selected which will be safe, provided the dam is specially designed to meet the particular set of geological conditions existing at the site selected.

Of the twelve possible sites studied in detail all those lying within the middle portion of the canyon (sites 1, 2, 3 and 4) are considered undesirable on account of their proximity to the Whittier fault, which is the major fault of the area.

This leaves the upper and lower ends of the canyon as the only locations where dam construction should be considered. Of these two general areas, the upper end is considered less desirable for dam construction because of the rather close proximity of the Chino fault which passes near Prado station, about 2500 feet east of the upper end of the canyon. Any dam built at the upper end of the canyon would lie between two major faults (the Whittier and Chino faults) and within about 2500 feet of one of them (the Chino fault).

It will be practically impossible to find any site in the canyon which is not either on or very near to one of the numerous faults which traverse the rocks of the entire region. Most of these faults, however, are of local extent and inactive, and are not necessarily a menace to the construction of dams specially designed to meet existing conditions.

Of the possible sites at the upper end of the canyon, sites 6 and 7, or some other site in the immediate vicinity of 6 or 7, seem to offer the only topographic and geological conditions worth further consideration. Final judgment as to whether any of these upper sites are suitable must be reserved until the results are obtained from certain excavations to be made to expose and study the formations. Also, it would be desirable to obtain more specific information as to the behavior of the sandstone and sandy shale, which constitute the side walls and bedrock of the upper end of the canyon in an open cut-off trench, and at the dam abutments when the reservoir level is lowered.

Of the five possible sites near the lower end of the canyon, sites 10, 11, and 12 seem to offer the fewest objectionable features. As in the case of the sites near the upper end, final judgment will again depend upon the results obtained from careful core-drilling to determine the exact nature of the bedrock beneath the alluvium of the river-bed and beneath the terrace gravels on the north bank. Such core-drilling should be carried to a depth of at least 100 feet into bedrock, which may mean 200 feet beneath the river. Further information on the behavior of the bedrock at sites 10, 11, and 12, in open cut-off trenches should also be obtained. It is also highly desirable to obtain good samples of the bedrock of sites 10, 11 and 12 upon which to make porosity and crushing tests.

At all of the possible sites in the lower canyon of the Santa Ana River the rock formations are soft and exhibit certain textural weaknesses. Therefore, regardless of what site may be finally selected it is recommended that special efforts be made to obtain complete data on the detailed conditions present through further drilling, trenching, or shaft sinking, and tests on the rock. Special care should be exercised to carry the cut-off wall into the bedrock for a greater distance than is usual in the case of granite foundations, and to anchor both ends of the structure as far as possible into the rock of the canyon walls beyond the zone of weathering and possible slumping.

Logs of Formations Encountered in Bore-Holes Drilled at Site 8

Hole 1

0 – 13.3 feet—silt and sand.
13.3– 45 feet—sand.
45 – 54 feet—coarse sand.
51 – 61 feet—sand.
61 – 73 feet—Sand with some gravel.
73 –123 feet—soft sandstone.
123 –131 feet—sandy shale.
131 –151 feet—soft sandstone.
No cores could be obtained.

Hole 2

0 – 20 feet—medium sand.
20 – 40 feet—clean medium sand.
40 – 48 feet—medium sand with some gravel.
48 – 55 feet—coarse sand.
55 – 69 feet—fine gravel and sand.
69 – 70 feet—clay, shale and fine sandstone (core).
70 – 74 feet—sand (core).
74 – 80 feet—shale.
80 – 86 feet—shale (core).
86 – 90 feet—sandy shale (core).
90 – 97 feet—whitish fine sand, no clay.
97 –120 feet—whitish fine sand, no clay.

Hole 3

0 – 5 feet—red clay silt.
5 – 12 feet—red clay silt, sandy.
12 – 20 feet—clean white sand.

20	– 25	feet—medium sand with ½" gravel pebbles.
25	– 30	feet—medium sand.
30	– 35	feet—fine sand, gray.
35	– 40	feet—fine sand, gray.
40	– 55	feet—medium sand.
55	– 60	feet—medium sand, gray or blue.
60	– 65	feet—fine sand, bluish.
65	– 70	feet—fine sand.

Bedrock soft, would not core.

Hole 4

0	– 8	feet—river sand.
8	– 28	feet—sand and gravel.
28	– 40	feet—gravel.
40	– 48	feet—sand and small gravel.
48	– 67	feet—gravel.
67	– 69	feet—brown sandstone.
69	– 70	feet—red sandstone.
70	– 74	feet—fine blue sandstone.
74	– 84	feet—brown sandstone, a few boulders and large pebbles.
84	– 85	feet—brown sandstone, a few boulders and large pebbles.
85	– 88	feet—blue sand.
88	– 93	feet—fine sand and red clay.
93	– 97	feet—coarse white sand.
97	–105	feet—red clay and fine sand.
105	–117	feet—sandy shale—not much clay.

(67-117 bedrock.)

Logs of formation encountered in bore-holes drilled at Site 6 (Chester Site)

Hole 5

0	– 10	feet—coarse sand.
10	– 18	feet—clean, white coarse sand.
18	– 23	feet—sand with some gravel.
23	– 28	feet—coarse sand similar to top sand.
28	– 34	feet—coarse gravel up to 3" diameter.
34	– 57	feet—coarse gravel (blasted on account of boulders).
57	– 81	feet—coarse gravel with rusty cement binder (boulders up to 10" dia.)
81	– 82	feet—loose sand and boulders. Bedrock at 82′.
82	– 95	feet—dark gray, soft clay shale.
95	–111	feet—dark gray, harder clay shale.
111	–114	feet—dark gray, hard clay shale with few paper-thin streaks of white sand.
114	–117	feet—Dark gray, hard clay shale (dip 73 degrees).
117	–131	feet—dark gray, hard clay shale (dip 80 degrees).
131	–136	feet—dark gray, hard clay shale (dip 80 degrees) with very little sand.
136	–148	feet—dark gray, hard clay shale (dip 80 degrees).
148	–156	feet—dark gray, hard clay shale (dip 85 degrees) slightly sandy.
156	–158	feet—dark gray, soft clay shale (bottom of hole).

Hole 6

0	– 7	feet—coarse river sand.
7	– 30	feet—coarse river sand and fine gravel.
30	– 39	feet—tight gravel with clay and boulders.
39	– 50	feet—clay and gravel with yellow clay binder.
50	– 52	feet—coarse gravel (bedrock at 52′).
52	– 58	feet—dark gray soft clay shale (dip 80 degrees).
58	– 67	feet—dark gray harder clay shale—slightly sandy.
67	– 83	feet—dark gray hard clay shale.
83	– 87	feet—dark gray hard clay shale (dip 75 degrees) slightly sandy.
87	– 90	feet—dark gray soft clay shale—would not core. Possible fracture zone.
90	– 97	feet—dark gray hard clay shale.
97	–102	feet—dark gray hard clay shale (dip 75 degrees).

Hole 7

0	– 10	feet—fine sand.
10	– 70	feet—coarse sand.
70	– 80	feet—medium sand.
80	– 82	feet—gravel and boulders (bed rock at 82′).
82	– 84	feet—dark gray clay shale; weathered.
84	– 90	feet—dark gray hard clay shale, slightly sandy (dip 75 degrees).
90	– 95	feet—dark gray hard clay shale.
95	–102	feet—dark gray soft clay shale.
102	–105	feet—dark gray soft clay shale with some conglomerate.
105	–111	feet—dark gray harder clay shale with slight amount of sand.
111	–118	feet—dark gray soft clay shale.
118	–121	feet—dark gray soft clay shale.
121	–127	feet—dark gray hard clay shale.
127	–132	feet—dark gray soft clay shale; broken (bottom of hole.)

Hole 8

0	– 65	feet—medium size river sand; no gravel (bedrock at 65′).
65	– 70	feet—dark gray soft sandy shale.
70	– 77	feet—dark gray hard shale (no dip visible in cores).
77	–100	feet—dark gray hard shale (no dip visible in cores).

NOTE.—About half of the water pumped into the hole seeped out at 117′. All of the water seeped out at 124′, indicating a fractured or faulted zone between 117′ and 124′.

Hole 9

0 – 36 feet—coarse river sand.
36 – 45 feet—white packed sand.
45 – 58 feet—coarse sand with some boulders; blasted (bedrock at 58').
58 – 67 feet—dark gray soft clay shale; broken cores; dip 85 degrees.
67 – 85 feet—dark gray hard clay shale; dip 85 degrees.
85 – 90 feet—dark gray hard clay shale; dip 85 degrees.

Hole 10 (250 feet northeast of hole 9)

0 – 13 feet—river sand (bedrock at 13').
13 – 20 feet—soft sandstone; no core obtained.
20 – 30 feet—yellowish, soft clay shale.
30 – 38 feet—dark gray soft sandy shale.
38 – 46 feet—dark gray soft sandy shale.
46 – 56 feet—dark gray soft sandy shale (poor cores).
56 – 66 feet—dark gray harder shale; fractured.
66 – 72 feet—dark gray harder shale; fractured.
72 – 75 feet—dark gray soft shale.

NOTE.—The hole is located on the north edge of the shale formation at the contact with the overlying sandstone. The entire core shows a softer, more sandy formation than the preceding cores, due to the fact that the hole is near the sandstone contact.

Hole 11

0 – 9 feet—river sand (bedrock at 9').
9 – 20 feet—yellowish weathered clay shale.
20 – 52 feet—dark gray, fairly hard shale with slight amount of sand. Cores badly broken.

Hole 12 (280 feet northeast of hole 8)

0 – 62 feet—fine river sand.
62 – 63 feet—gravel.
63 – 68 feet—coarse gravel with boulders (bedrock at 68').
68 – 73 feet—hard sandy shale; dip 85 degrees.
73 – 83 feet—conglomerate.
83 – 89 feet—hard sandy shale and sandstone (no core obtained).
89 – 93 feet—soft sandy shale.
93 –100 feet—soft sandy shale (broken cores).

NOTE.—This hole is in the contact zone, or immediately north of the contact between the shale formation and the overlying sandstone.

Logs of Formations Encountered in Bore-Holes Drilled at Site 12 (Lower Prado Site.) (Drilled With Churn Drill. No Cores Obtained.)

Hole 1

0 – 49 feet—gravel, sand and silt; some boulders (bedrock at 49').
49 – 50 feet—dark clay shale
50 – 50½ feet—sandstone.
50½ – 51 feet—soft clay shale.
51 – 70 feet—dark gray shale.
70 – 71 feet—sandstone.
71 – 75 feet—hard gray shale.
75 – 75½ feet—hard sandstone.
75½ – 80 feet—hard sandy shale.
80 – 86 feet—shale containing coarse sand.
86 – 87 feet—sandstone.
87 –114 feet—hard massive shale.
114 –124 feet—softer shale containing a little sand.
124 –138 feet—shale with thin sandstone layers.
138 –139 feet—hard sandstone.
139 –180 feet—dark gray clay shale.
180 –200 feet—dark gray clay shale.

Hole 2

0 – 59 feet—coarse sand and gravel, with some boulders.
59 – 62 feet—dark gray soft clay shale.
62 – 64 feet—sandstone.
64 – 65 feet—dark gray clay shale.
65 – 85 feet—sandy shale.

Hole 3

0 – 40 feet—gravel, sand and clay.
40 – 75 feet—water-gravel containing boulders up to 6".
75 – 77½ feet—boulders and gravel (bedrock at 77½').

Hole 4a, 4b, 4c

Drill could not penetrate boulder bed between 24' and 30'.

Hole 4d (near 4a, 4b and 4c)

0 – 11 feet—river sand.
11 – 15 feet—river sand and big boulders.
15 – 25 feet—river sand and gravel.
25 – 30 feet—coarse gravel with some boulders.

30 – 35 feet—sand and gravel.
35 – 42 feet—sand.
42 – 52 feet—sand and boulders.
52 – 60 feet—gravel and boulders.
60 – 70 feet—gravel and boulders up to 10″.
70 – 75 feet—gravel and boulders up to 6″.
75 – 80 feet—gravel and boulders up to 4″.
80 – 82 feet—coarse river sand (bedrock at 82′).
82 – 96 feet—soft gray sandstone, somewhat shaley.
96 –104 feet—dark gray sandy shale and shaley sandstone.
104 –106 feet—dark gray sandy shale.
106 –111 feet—dark gray shaley sandstone.
111 –124 feet—dark gray clay shale.
124 –127 feet—dark gray sandy shale.
127 –130 feet—dark gray shale.
130 –133 feet—dark gray soft shale.
133 –135 feet—sandstone.
135 –141 feet—dark gray sandy shale.
141 –147 feet—dark gray shale.
147 –150 feet—dark gray sandy shale (bottom of hole).

Hole 5

0 – 10 feet—silt and loam.
10 – 15 feet—coarse sand and gravel.
15 – 20 feet—coarse sand and gravel (few 3″ boulders).
20 – 25 feet—coarse sand and gravel.
25 – 30 feet—coarse sand and gravel with some clay streaks.
30 – 35 feet—coarse sand and gravel.
35 – 40 feet—coarse gravel (with some 10″ bounders).
40 – 45 feet—coarse gravel (with some 8″ boulders).
45 – 50 feet—coarse gravel (with some 6″ boulders).
50 – 55 feet—coarse gravel (with some 2″ boulders).
55 – 60 feet—sand and gravel (with some 4″ boulders).
60 – 66 feet—sand and gravel (bedrock at 66′).
66 – 73 feet—sandstone with some shale streaks.
73 – 77 feet—sandy shale.
77 – 78 feet—sand and shale.
78 – 85 feet—hard shale.
85 – 95 feet—sandstone (soft).
95 –100 feet—shale.
100 –115 feet—sandstone.
115 –117 feet—sandstone and shale.
117 –132 feet—hard shale.
132 –135 feet—shale and sandstone—thin layers interbedded.
135 –150 feet—hard dark gray shale.

PLATE 22

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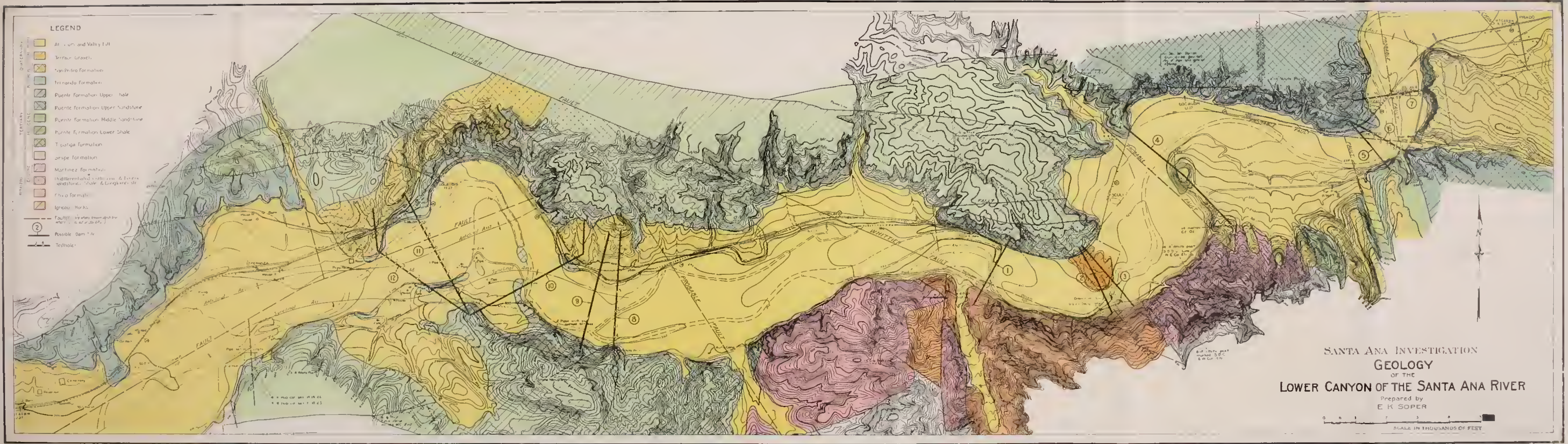
LEGEND
Terrace Gravels
Puente Formation Upper Shale
Puente Formation Upper Sandstone
Puente Formation Middle Sandstone
Puente Formation Lower Shale
Martinez Formation
Possible Dam Site
Testholes
WHITTIER
FAULT
SANTA ANA INVESTIGATION
GEOLOGY
OF THE
LOWER CANYON OF THE SANTA ANA RIVER
Prepared by
E K SOPER
SCALE IN THOUSANDS OF FEET

63685

SUPPLEMENTARY REPORT*

December 1, 1928.

In the summary of my report on the geology of the lower canyon of the Santa Ana River, submitted July 2, 1928, it was pointed out, page 261, that final judgment as to whether any of the sites studied and described would prove to be suitable for dam construction should be reserved until the results were obtained from excavations then being made to expose the bedrock formations in certain places beneath the overlying mantle of terrace and river gravels.

Since the above-mentioned report was submitted, most of the excavations referred to have been completed under the supervision of Mr. Chester Marliave, geologist for the Orange County Flood Control. I have recently had an opportunity to examine the bedrock formations exposed in these excavations, and in this supplementary report the conclusions reached from a study of these exposures of bedrock are set forth.

Site 6 (*Chester Site*). On page 255 of this report, reference is made to certain test-holes which were bored in the river bed along the axis of Site 6, in order to obtain additional data which might bear upon the possible existence of a fault across the river at this site. Eight holes were drilled in the river bed at Site 6. The locations of these holes are shown on Plate 22. The data obtained from the eight holes above mentioned did not show definite evidence bearing upon the possible existence of a fault at this location. In holes 5, 7, and 10 the shale was found to be slightly fractured near the bottom of the holes, but the fracturing could be due to causes other than faulting. The samples of shale obtained from the holes were tough and fairly hard.

After the completion of the eight test-holes above mentioned, a deep trench was excavated across the arroyo, immediately east of the River Bank Camp, and north of the south end of Site 6. This trench was located in such a position that it would cross any east-west fault which might extend up this arroyo. Bedrock was encountered at both ends of this trench for a distance of about 40 feet outward from the sides of the arroyo. Because of the depth of the alluvium and the large quantity of water encountered, bedrock was not reached in the middle part of the trench. A careful examination of the bedrock at both ends of the trench showed no evidence of faulting, nor breaks of any kind. The bedrock in the north end of the trench is sandstone, and in the south end, sandstone alternating with shale. This test was not absolutely conclusive, since the trench did not expose the bedrock in the central part of the arroyo. The topography, and especially the Quaternary terrace gravels, suggest that an east-west fault might extend along the arroyo, but the rock exposures do not confirm this.

Site 7 (*Upper or Prado Site*). A deep trench was dug in the sandstone bedrock formation at the east end of Site 7. The purpose of this trench was to study the action of the sandstone bedrock when immersed in water. The trench was filled with water, and after standing for one month there was no evidence of sloughing of the sandstone on the sides of the trench under the water. This was rather surprising since

* By E. K. Soper.

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* By E. K. Soper.

the same sandstone is soft and crumbly on the sides of natural embankments where it has undergone weathering under ordinary atmospheric conditions.

As pointed out in the report, the topography and configuration of the river channel in this vicinity strongly suggest the possibility of a fault extending beneath the river bed, and parallel to the river valley at Site 7. However, if such a fault occurs, it can not be detected in the rock exposures, which indicate that the same formation is continuous across the river valley here.

Site 12 (Lower Site). At Site 12, seven deep pits are being excavated in order to ascertain the character of the bedrock and the depth of the terrace and river gravels overlying the bedrock at this locality. Pit No. 1 is located in the river bottom at the immediate base of the embankment on the north side of the river near the axis of the proposed dam. Pit No. 2 is located on the terrace above the embankment about 250 feet north of Pit No. 1. Pit No. 3 is located in the river bottom at the foot of the embankment on the north side of the river about 400 feet northeast of Pit No. 2. Pit No. 7 is located in the bottom of a small arroyo about 700 feet northwest of Pit No. 2. Pits Nos. 4, 5, and 6 are located on the terrace on the south side of the river, near the south end of the site. At the time this is written, Pits Nos. 1, 2, 3 and 6 are the only ones completed.

Pit No. 1. Pit No. 1 started in bedrock and was excavated in rock all the way to a total depth of 56 feet. The rock consists of alternating strata of sandstone and shale. The shale, which predominates, is quite hard and tough. It was necessary to blast this rock. Water, standing in the bottom of the hole for several weeks, had no apparent effect upon the shale which stood firmly in the vertical sides of the hole with no evidence of softening or sloughing. The formation is similar to that exposed near the river level at the bases of the terraces along the north and south ends of Site 12. The shale becomes harder at depth.

Pit No. 2. Pit No. 2 reached a depth of 36 feet without finding bedrock. River gravel, sand, and alluvium were penetrated. Water which seeped into the pit in large quantities prevented the workmen from deepening it to bedrock.

Pit No. 3. The depth of Pit No. 3 is 34 feet. Bedrock was encountered at 30 feet. The bedrock consists of the same alternating shale and thin layers of sandstone as found in Pit No. 1. The shale is massive, tough, and fairly hard, and similar to that encountered in Pit No. 1.

Pit No. 6. Pit No. 6 exposed the bedrock at a depth of about 30 feet and shows that the strata dip towards the river at this point. The rock is sandstone and sandy shale.

In addition to the deep pits described above, five bore-holes were drilled along the axis of Site 12 beneath the present river bottom. The logs of these holes and the formations encountered have already been given in this report. The holes varied in depth from 77 to 200 feet. The formations encountered in these bore-holes are similar to those encountered in the four deep pits described above.

The pits, bore-holes, and other excavations indicate that the same formation of alternating shale and sandstone is continuous from the north to the south end of Site 12. Hard, tough shale predominates beneath the river bed.

On page 259 of the report, reference is made to the possibility of a fault beneath the river bed about one-half mile downstream from Site 12, extending in a general east-west direction along the river bed, and which, if projected eastward, would pass near the north end of Site 12. The test-pits and bore-holes described above did not furnish any additional evidence bearing on the existence or nonexistence of such a fault. The bore-holes in the river bottom, the locations of which are shown on Plate 22, were made with a churn-drill, and did not give very definite information regarding the hardness and character of the bed-rock beneath the middle of the river bed, nor did these bore-holes furnish any data bearing upon the possible existence of fractures in the bedrock beneath the center of the river bed. It is recommended that additional bore-holes be put down with a core-drill along the axis of Site 12, in order to obtain, if possible, additional data bearing upon the existence or nonexistence of a fault beneath the river at Site 12. However, even core-drill holes might fail to settle this question of the possible eastward extension of the above-mentioned fault, since a fault line between two adjacent drill-holes might be missed. The topographic relations at Site 12 are less suggestive of faulting than at Sites 6 and 7. Moreover, if a fault exists here, the displacement is small.

The question of the possibility of faults beneath the river bed at Sites 6, 7, and 12 must remain somewhat in doubt until a cut-off trench is excavated to bedrock across the entire river valley. If faults extend along the river valley at one or more of these sites, they are of the class commonly called "dead" faults, since the topography shows no indication of recent movement of the ground.

The two best locations from a geological viewpoint are Sites 12 and 6, with Site 12 offering the fewest unfavorable geologic features.

It should be emphasized that the rock formations and geologic structure throughout the lower Santa Ana River Canyon are such that certain types of dams would be unsafe. The formations are unsuited for withstanding heavy concentrated loads. On the other hand, the formations at Sites 12 and 6 should safely withstand heavy loads well distributed. Finally, any dam to be constructed should be specially designed for the special set of geological conditions existing at the site selected.

PART III

HYDROGRAPHIC DATA

CHAPTER 1

UNPUBLISHED DISCHARGE RECORDS OF U. S. GEOLOGICAL SURVEY

Records of U. S. Geological Survey. Water Supply Paper, No. 447, is a compilation of all records up to and including September 30, 1918. Water Supply Papers, Nos. 511, 531, 551, 571 continue all records to September 30, 1923.

By courtesy of the U. S. Geological Survey, permission has been given to print provisional figures continuing these reports to September 30, 1928. Records for 1928 are preliminary.

The list of the U. S. Geological Survey gaging stations in the Santa Ana watershed is given in the table of contents. For reference in this report a gage station index number has been added. Map 4 in pocket and plate No. 9, page 184, show location of these stations by this index number.

1–4. SAN ANTONIO CREEK NEAR CLAREMONT

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	50.4	27.1	14.8	30.7	78.7
November	53.6	39.3	17.3	84.5	85.7
December	52.3	34.4	22.1	62.1	105.0
January	49.8	26.4	31.4	37.5	93.5
February	46.0	22.2	181.0	4,520.0	106.0
March	72.6	33.8	42.4	2,720.0	108.0
April	115.0	97.6	4,170.0	1,210.0	72.0
May	43.7	38.7	1,600.0	922.0	40.3
June	23.2	23.8	152.0	180.0	19.6
July	17.8	13.5	53.5	87.9	18.0
August	16.0	11.7	37.5	76.9	13.5
September	15.5	11.3	35.7	78.6	11.9
Totals	556.0	380.0	6,360.0	10,000.0	752.0

1–5. SOUTHERN CALIFORNIA EDISON CO.'S CANAL NEAR CLAREMONT

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	590	374	316	571	670
November	555	364	305	524	619
December	518	399	317	719	627
January	512	393	314	775	609
February	462	347	397	933	713
March	507	384	521	1,540	824
April	708	480	1,240	1,490	839
May	1,000	682	1,330	1,510	750
June	666	536	1,370	1,420	601
July	495	414	1,060	1,090	513
August	418	331	824	855	438
September	367	306	631	726	386
Totals	6,830	5,010	8,620	12,200	7,590

10-1. LYTLE CREEK NEAR FONTANA

Monthly run-off in acre-feet

Month	1923-1924	1924-1925	1925-1926	1926-1927	1927-1928
October					
November					
December				1.8	
January					
February			50.0	5,890.0	
March				1,020.0	
April			940.0	180.0	
May					
June					
July					
August					
September					
Totals			990.0	7,090.0	

NOTE—Dry on months for which no run-off is given.

10-3. FONTANA PIPE LINE NEAR FONTANA

Monthly run-off in acre-feet

Month	1923-1924	1924-1925	1925-1926	1926-1927	1927-1928
October	1,680	806	682	1,570	2,020
November	1,520	827	744	1,560	1,530
December	1,510	842	769	1,540	1,650
January	1,280	916	824	1,320	1,520
February	1,260	822	1,270	2,010	1,550
March	1,520	935	904	3,040	1,540
April	1,450	1,080	2,340	2,670	1,480
May	1,510	1,080	2,090	2,340	1,420
June	1,220	1,010	1,420	2,420	1,280
July	1,040	873	1,320	3,060	1,030
August	898	756	1,180	2,870	910
September	809	690	1,170	2,360	821
Totals	15,700	10,600	14,700	26,800	16,800

11-1. LONE PINE CREEK NEAR KEENBROOK

Monthly run-off in acre-feet

Month	1923-1924	1924-1925	1925-1926	1926-1927	1927-1928
October	83.0	32.6	19.1	6.1	8.3
November	65.5	35.7	16.7	20.2	9.7
December	78.1	35.7	17.8	9.8	11.7
January	71.9	34.4	18.4	10.5	13.5
February	67.9	30.5	55.0	142.0	20.4
March	93.5	32.0	15.4	32.6	11.7
April	84.5	44.0	91.0	26.8	10.7
May	65.2	29.5	19.1	25.2	6.1
June	48.8	28.6	15.5	18.4	6.0
July	41.2	25.2	12.3	15.4	6.1
August	36.3	21.5	11.1	12.3	7.4
September	32.1	17.9	6.5	10.1	7.1
Totals	768.0	368.0	298.0	329.0	119.0

12–1. CAJON CREEK NEAR KEENBROOK

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	212	177	138	109.0	87.3
November	217	158	148	151.0	114.0
December	267	203	163	300.0	168.0
January	260	207	185	171.0	153.0
February	259	186	544	2,370.0	304 0
March	457	220	212	769.0	207.0
April	394	338	1,280	515.0	156.0
May	221	159	293	243.0	140.0
June	176	140	172	173.0	99.4
July	140	107	111	113.0	87.3
August	121	102	108	106 0	81.8
September	158	105	97	92.2	83.9
Totals	2,880	2,100	3,450	5,110.0	1,680.0

20-1. DEVIL'S CANYON CREEK NEAR SAN BERNARDINO

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	32 0	12.3	0	0	6.1
November	44.0	61.9	0	4.2	6.0
December	52.3	70.7	0	58.4	24.6
January	64.0	61.5	0	53.5	16.6
February	63.3	85 5	178.0	916.0	81.7
March	181.0	92.8	14.8	536.0	12.9
April	252.0	134.0	857.0	354.0	7.7
May	62.1	16.0	46.1	124.1	6.1
June	16.0	16.1	13.1	10.1	3 0
July	3.1	11.1	0	6.1	0
August	3.7	0	0	6.1	0
September	0	0	0	6.0	0
Totals	774.0	562.0	1,110.0	2,070.0	165 0

21–1. WATERMAN CANYON CREEK NEAR ARROWHEAD SPRINGS

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	57.8	17.8	22.8	7.4	32.5
November	85.1	46.4	25.0	23.2	64.3
December	87.3	59.0	38.1	81.8	69.5
January	81.8	54.1	44.3	83.0	72.6
February	63.8	56.6	156.0	711.0	163.0
March	150.0	68.9	48.0	504.0	89.8
April	160.0	101.0	595.0	271.0	64.9
May	60.9	71.3	163.0	204.0	47.8
June	25.0	59.5	44.0	96.4	23.6
July	6.8	15.4	20.3	24.6	7.0
August	0.6	2.5	3.7	14.8	0
September	0.6	2.4	3.0	17.9	0
Totals	784.0	555.0	1,160.0	2,040.0	635.0

22-1. STRAWBERRY CREEK NEAR ARROWHEAD SPRINGS

Monthly run-off in acre-feet

	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	106.0	67.6	68.2	67.0	86.7
November	114.0	119.0	78.6	97.0	133.0
December	117.0	160.0	104.0	192.0	187.0
January	164.0	111.0	103.0	153.0	168.0
February	123.0	141.0	262.0	1,430.0	264.0
March	338.0	218.0	103.0	652.0	186.0
April	323.0	268.0	1,260.0	467.0	116.0
May	136.0	125.0	255.0	274.0	91.0
June	76.2	148.0	120.0	186.0	38.9
July	41.2	35.0	73.2	94.1	18.4
August	28.3	20.3	53.5	51.0	18.3
September	30.3	20.2	44.0	52.4	11.9
Totals	1,600.0	1,430.0	2,520.0	3,720.0	1,320.0

26-1. CITY CREEK NEAR HIGHLAND

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	186.0	16.6	94.1	0	75.6
November	339.0	109.0	22.6	109.0	265.0
December	274.0	290.0	116.0	433.0	335.0
January	251.0	52.3	17.8	344.0	377.0
February	20.1	147.0	789.0	6,390.0	512.0
March	640.0	294.0	11.1	1,520.0	238.0
April	1,130.0	678.0	8,810.0	1,200.0	24.0
May	59.6	76.9	689.0	328.0	42.4
June	0	87.5	75.6	79.1	0
July	0	0	0	3.1	0
August	0	0	0	0	0
September	0	0	0	0	0
Totals	2,900.0	1,750.0	10,600.0	10,400.0	1,870.0

26-2. CITY CREEK WATER CO.'S CANAL NEAR HIGHLAND

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	------------	97.2	67.6	131.0	94.7
November	------------	109.0	153.0	131.0	31.4
December	------------	92.8	96.5	0	70.1
January	------------	239.0	177.0	0.4	30.7
February	------------	159.0	37.2	2.2	49.9
March	------------	255.0	236.0	0	150.0
April	------------	171.0	30.9	20.8	245.0
May	------------	280.0	263.0	366.0	173.0
June	190.0	193.0	435.0	455.0	134.0
July	101.0	103.0	271.0	284.0	49.0
August	75.0	56.0	165.0	166.0	29.9
September	75.6	64.9	119.0	141.0	23.8
Totals	------------	1,820.0	2,050.0	1,700.0	1,080.0

29–1. PLUNGE CREEK NEAR EAST HIGHLAND

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	0	0	3.7	0	9.8
November	1.8	15.5	7.1	36.3	56.5
December	24.6	52.9	15.4	113.0	110.0
January	30.7	1.8	4.9	108.0	111.0
February	4.6	5.6	461.0	4,590.0	214.0
March	181.0	27.7	2.5	941.0	143.0
April	690.0	309.0	4,110.0	550.0	1.8
May	12.9	16.6	285.0	76.9	36.9
June	1.8	18.4	0	6.0	0
July	0	0	0	0	0
August	0	0	0	0	0
September	0	0	0	0	0
Totals	947.0	448.0	4,890.0	6,420.0	683.0

31–1. SANTA ANA RIVER NEAR MENTONE

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	102.0	65.2	118.0	64.6	127.0
November	104.0	88.7	47.6	202.0	136.0
December	87.3	137.0	49.2	366.0	162.0
January	85.5	69.5	50.4	192.0	162.0
February	63.8	72.8	455.0	42,800.0	439.0
March	713.0	124.0	726.0	4,610.0	133.0
April	863.0	255.0	11,800.0	1,490.0	130.0
May	119.0	101.0	1,960.0	1,370.0	114.0
June	88.7	102.0	104.0	274.0	95.2
July	62.7	1,120.0	89.8	221.0	109.0
August	55.3	66.4	80.6	195.0	82.4
September	58.9	40.5	75.0	156.0	61.9
Totals	2,400.0	2,240.0	15,600.0	51,900.0	1,750.0

31–2. SOUTHERN CALIFORNIA EDISON CO.'S CANAL NEAR MENTONE

Monthly run-off in acre-feet

Month	1923-1924	1924–1925	1925-1926	1926–1927	1927–1928
October	4,480	4,170	2,120	3,650	3,680
November	3,250	2,020	1,890	2,770	1,780
December	2,590	2,100	1,340	2,110	1,570
January	2,180	1,800	1,170	2,360	1,800
February	1,910	2,080	2,300	3,190	2,190
March	2,550	2,320	1,130	4,290	1,890
April	4,820	3,210	0	5,110	1,810
May	4,460	3,360	2,760	4,220	2,520
June	4,250	3,170	3,630	4,150	3,020
July	4,570	2,740	4,160	4,430	3,270
August	4,830	4,240	4,380	4,510	3,310
September	4,670	4,030	4,050	4,170	3 000
Totals	44,600	35,200	28,900	45,000	29,800

31–3. GREENSPOT PIPE LINE NEAR MENTONE

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	418	488	181	288.0	461.0
November	298	295	248	170.0	198.0
December	135	186	246	36.9	347.0
January	172	246	246	36.9	29.5
February	196	100	200	164.0	.0
March	184	274	232	135.0	371.0
April	298	487	0	149.0	478.0
May	332	553	317	379.0	418.0
June	455	536	218	536.0	502.0
July	473	417	209	553.0	492.0
August	544	537	232	485.0	507.0
September	524	409	262	536.0	428.0
Totals	4,030	4,530	2,590	3,470.0	4,230.0

33–1. MILL CREEK NEAR CRAFTONVILLE

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	0	0	0	0	3.1
November	0	0	0	151.0	5.4
December	0	0	0	35.7	8.0
January	0	0	0	0	4.9
February	0	0	224.0	7,500.0	87.4
March	87.3	0	0	2,200.0	8.6
April	583.0	0	3,300.0	2,120.0	6.6
May	139.0	0	2,590.0	3,600.0	6.1
June	0	0	738.0	1,680.0	6.6
July	0	0	0	99.0	0
August	0	0	0	6.8	0
September	0	0	0	8.9	0
Totals	809.0	0	6,850.0	17,500.0	137.0

33–2. MILL CREEK POWER CANAL Nos. 2 AND 3 NEAR CRAFTONVILLE

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	1,340	836	595	1,030	1,320
November	1,220	875	684	964	1,210
December	1,210	996	570	1,030	1,120
January	1,240	898	658	1,070	1,030
February	1,060	805	811	1,060	1,090
March	1,140	959	953	1,680	1,150
April	1,650	1,290	1,590	1,890	1,190
May	1,970	1,180	1,830	1,750	1,180
June	1,490	904	1,830	1,880	976
July	1,060	713	1,780	1,900	812
August	830	707	1 510	1,860	646
September	786	649	1,120	1,470	589
Totals	15,000	10,800	13,900	17,600	12,300

33–3. MILL CREEK POWER CANAL No. 1 NEAR CRAFTONVILLE

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	142.0	95.3	71.9	45.5	62.1
November	133.0	115.0	54.2	53.0	114.0
December	160.0	156.0	173.0	101.0	146.0
January	146.0	123.0	89.8	130.0	168.0
February	120.0	112.0	151.0	143.0	269.0
March	198.0	144.0	111.0	604.0	300.0
April	273.0	162.0	14.3	450.0	132.0
May	244.0	124.0	0	493.0	59.6
June	115.0	110.0	62.5	386.0	35.7
July	87.9	169.0	191.0	664.0	22.4
August	82.4	79.9	165.0	208.0	20.0
September	73.8	31.5	53.6	109.0	15.6
Totals	1,780.0	1,420.0	1,140.0	3,390.0	1,340.0

A–2. MEEKS & DALEY CANAL NEAR COLTON

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	652	732	439.0	1,030.0	646.0
November	371	607	421.0	690.0	41.6
December	272	172	187.0	0	143.0
January	251	232	396.0	93.5	13.5
February	418	307	11.1	126.0	28.8
March	239	323	408.0	0	259.0
April	167	334	288.0	54.1	714.0
May	1,030	707	454.0	928.0	806.0
June	970	898	964.0	1,010.0	1,010.0
July	1,050	1,030	1,100.0	1,010.0	1,000.0
August	1,070	1,030	1,080.0	910.0	990.0
September	893	940	994.0	756.0	1,060.0
Totals	7,380	7,310	6,740.0	6,610.0	6,710.0

A–3. WARM CREEK NEAR COLTON

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	3,540	3,130	3,020	2,590	2,850
November	4,400	3,230	3,120	2,920	3,430
December	4,970	4,590	3,900	4,080	3,820
January	5,360	4,380	3,530	3,830	4,330
February	4,830	3,730	3,940	9,550	4,080
March	5,340	4,510	3,330	4,970	3,690
April	5,370	4,320	10,700	4,520	2,090
May	4,180	3,400	4,320	3,060	2,470
June	3,670	3,000	2,940	2,760	2,090
July	3,330	2,900	2,540	2,230	1,750
August	3,120	2,710	2,330	2,140	1,760
September	2,680	2,420	2,330	2,110	1,520
Totals	50,800	42,300	46,000	44,800	34,900

C-1. SANTA ANA RIVER NEAR PRADO

Monthly run-off in acre-feet

Month	1923-1924	1924-1925	1925-1926	1926-1927	1927-1928
October	6,150	5,870	6,700	4,510	4,570
November	8,930	6,900	5,570	6,250	7,380
December	11,400	9,280	9,530	10,200	10,600
January	13,500	11,600	7,130	11,300	11,700
February	8,800	8,660	14,400	72,200	14,500
March	14,700	7,320	8,610	20,500	10,900
April	19,800	9,880	37,500	13,400	6,010
May	6,120	5,830	7,690	6,120	5,820
June	4,260	4,810	4,410	4,370	3,700
July	3,760	3,510	3,550	3,290	2,580
August	3,420	3,500	3,250	3,140	2,340
September	3,950	3,830	3,480	3,340	2,530
Totals	105,000	81,000	112,000	159,000	79,600

E-1. SANTA ANA RIVER AT SANTA ANA

Monthly run-off in acre-feet

Month	1923-1924	1924-1925	1925-1926	1926-1927	1927-1928
October					
November	145.0			99.4	114.0
December	234.0	144.0		309.0	217.0
January	818.0	70.7		194.0	135.0
February	123.0	.0	223.0	57,200.0	811.0
March	154.0	8.6	6.1	6,150.0	227.0
April	215.0	251.0	21,300.0	2,980.0	28.1
May	35.7	.0	113.0	92.2	.0
June					
July					
August					
September					
Totals	1,720.0	474.0	21,600.0	67,000.0	1,530.0

Note—Dry on months for which no run-off is given.

50-1. SANTIAGO CREEK NEAR VILLA PARK

Monthly run-off in acre-feet

Month	1923-1924	1924-1925	1925-1926	1926-1927	1927-1928
October					25.8
November				156.0	155.0
December	19.1		10.5	377.0	103.0
January	9.8		3.1	177.0	26.4
February			307.0	22,300.0	376.0
March	17.8			4,600.0	110.0
April	7.1	15.5	7,200.0	1,070.0	4.0
May			248.0	59.6	
June					
July					
August					
September					
Totals	53.8	15.5	7,770.0	28,700.0	800.0

Note—Dry on months for which no run-off is given.

50–2. SERRANO & CARPENTER CANAL NEAR VILLA PARK

Monthly run-off in acre-feet

Month	1923–1924	1924–1925	1925–1926	1926–1927	1927–1928
October	171.0	92.2	75.6	264.0	254.0
November	142.0	60.7	72.6	156.0	153.0
December	106.0	62.1	68.2	140.0	92.2
January	92.2	65.8	61.5	137.0	165.0
February	86.9	53.3	80.0	73.3	138.0
March	83.0	50.4	119.0	91.0	231.0
April	92.8	43.4	127.0	206.0	319.0
May	80.6	40.0	476.0	467.0	298.0
June	137.0	29.2	389.0	400.0	284.0
July	230.0	24.0	456.0	539.0	349.0
August	159.0	31.4	410.0	403.0	242.0
September	119.0	67.2	320.0	311.0	162.0
Totals	1,500.0	620.0	2,650.0	3,190.0	2,690.0

CHAPTER 2

STREAM DISCHARGE RECORDS AT STATIONS MAINTAINED BY SANTA ANA INVESTIGATION

Records of the State Stations, operated in the Santa Ana Investigation: In the fall of 1927 a series of gaging stations were established to measure all streams not already measured by the U. S. Geological Survey. These stations were fitted with staff gages. On major streams water stage registers and cables or bridges for measuring high flood discharge were installed.

The following list comprises the state stations in the Santa Ana watershed. To these have been added the station maintained by the city of Redlands on San Timoteo Creek, stations operated by Orange County Flood Control, and a station operated by Los Angeles County Flood Control. In the tabulations, estimated values are indicated by "e."

For reference an index number has been assigned to each gage station. This index number appears on Plate 9, page 184, showing locations of stations.

SAN ANTONIO CREEK SPREADING INTAKE NEAR CLAREMONT, STATE GAGE STATION INDEX No. 1-1

Location.—In Sec. 23, T. 1 N., R. 8 W., on Camp Baldy road, 2 miles north of Base Line road on Los Angeles County line, near Claremont.

Drainage area.—None.

Records available.—October 1, 1927, to September 30, 1928.

Gage.—Water stage recorder on west bank of channel.

Discharge measurements.—Made by wading near gage.

Channel and control.—One channel, concrete control.

Extremes of discharge.—Maximum stage recorded during period, 0.07 ft. February 7 (discharge, 0.1 sec.-ft.); minimum discharge, dry.

Diversions.—Numerous diversions above station. Only waters for spreading pass this station.

Regulation.—None.

Accuracy.—No rating curve obtainable this season.

Cooperation.—Los Angeles County Flood Control.

Discharge measurements San Antonio Creek spreading intake near Claremont State Gage Station Index No. 1-1

For the year ending September 30, 1928

Date, 1928	Made by	Gage height, feet	Discharge, second-feet	Date, 1928	Made by	Gage height, feet	Discharge, second-feet
January 22	W. S. Post	0	0	March 3	W. S. Post	0	0
February 3	K. B. Forbes	0	0	March 4	L. Berger	0	0
February 4	W. S. Post	0	0	March 5	L. Berger	0	0
February 5	W. S. Post	.06	0.1	March 7	L. Berger	0	0
February 7	F. W. Bush	.07	0.1	March 9	L. Berger	0	0
February 16	L. Berger	0	0	March 12	L. Berger	0	0
February 20	L. Berger	0	0	March 16	L. Berger	0	0
February 25	L. Berger	0	0	March 19	L. Berger	0	0
February 27	L. Berger	0	0	March 26	L. Berger	0	0
March 1	L. Berger	0	0	March 30	L. Berger	0	0

Daily discharge in second-feet of San Antonio Creek spreading intake near Claremont, State Gage Station Index No. 1–1

For the year ending September 30, 1928

Day	February	Day	February	Day	February
1	0	11	0	21	0
2	0	12	0	22	0
3	0	13	0	23	0
4	0	14	0	24	0
5	0.1	15	0	25	0
6	0.1	16	0	26	0
7	0.1	17	0	27	0
8	0	18	0	28	0
9	0	19	0	29	0
10	0	20	0		

NOTE.—Dry on months for which no discharge is given.

Monthly discharge of San Antonio Creek spreading intake near Claremont, State Gage Station Index No. 1–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
January	0	0	0	0
February	.1	0	.01	0.6
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
Totals for the year	.1	0	0	0.6

SAN ANTONIO CREEK SPREADING WASTE NEAR CLAREMONT, STATE GAGE INDEX No. 1–2

LOCATION.—In Sec. 24, T. 1 N., R. 8 W., south of Camp Baldy road, 2 miles north of Base Line road on Los Angeles-San Bernardino County line.

DRAINAGE AREA.—27.5 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Water-stage recorder on east bank of channel.

DISCHARGE MEASUREMENTS.—Made by wading at low water and from cable at high water.

CHANNEL AND CONTROL.—One channel at all stages; concrete control.

EXTREMES OF DISCHARGE.—Maximum stage recorded during period, 0.26 ft. February 4, 1928 (discharge, 70 sec.-ft.); minimum discharge, dry.

DIVERSIONS.—Numerous diversions above this station for power and irrigation.

ACCURACY.—Stage discharge relation permanent during season rating curve well defined up to 70 sec.-ft. Daily discharge ascertained by applying mean daily gage height to rating table. Water-stage recorder gave fair record from time of installation; February 2, 1928. Record fair.

Rating table of San Antonio Creek, spreading waste, near Claremont, State Gage Station Index No. 1–2

Gage height	Discharge second-feet
— .20	0
— .10	1.0
0.00	2.1
0.05	4.0
0.10	11.2
0.15	25.2
0.20	45.0
0.25	66.0
0.26	70.0

Discharge measurements of San Antonio Creek, spreading waste, near Claremont, State Gage Station Index No. 1–2

During year ending September 30, 1928

Date, 1928	Made by	Gage height, feet	Discharge, second-feet	Date, 1928	Made by	Gage height, feet	Discharge, second-feet
January 23	W. S. Post	0	0	March 3	W. S. Post	0	0
February 2	Bush and Case	0	0	March 4	L. Berger	0	0
February 3	K. Forbes	0	0	March 5	L. Berger	0	0
February 4	W. S. Post	.26	70.0	March 7	L. Berger	0	0
February 7	F. W. Bush	.02	2.2	March 9	L. Berger	0	0
February 9	W. S. Post	–.10	1.0	March 12	L. Berger	0	0
February 16	F. W. Bush	0	0	March 16	L. Berger	0	0
February 20	F. W. Bush	0	0	March 19	L. Berger	0	0
February 24	F. W. Bush	0	0	March 26	L. Berger	0	0
February 27	L. Berger	0	0	March 30	L. Berger	0	0
March 1	L. Berger	0	0				

Daily discharge in second-feet of San Antonio Creek, spreading waste, near Claremont, State Gage Station Index No. 1–2

For the year ending September 30, 1928

Day	February	Day	February	Day	February
1	0	11	0	21	0
2	0	12	0	22	0
3	0	13	0	23	0
4	20	14	0	24	0
5	2	15	0	25	0
6	1	16	0	26	0
7	1	17	0	27	0
8	1	18	0	28	0
9	1	19	0	29	0
10	0	20	0		

NOTE.—Dry on months for which no discharge is given.

Monthly discharge of San Antonio Creek, spreading waste, near Claremont, State Gage Station Index No. 1–2

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
January	0	0	0	0
February	20.0	0	.90	52.0
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	.0	0
August	0	0	0	0
September	0	0	0	0
Totals for the year	20.0	0	0.075	52.0

SAN ANTONIO CREEK AT POWER HOUSE No. 1 BRIDGE, NEAR CLAREMONT, STATE GAGE STATION INDEX No. 1–3

LOCATION.—In SW¼, Sec. 13, T. 1 N., R. 8 W., at Ontario Power House No. 1 bridge, on Camp Baldy road, near Claremont.

DRAINAGE AREA.—25 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff painted on downstream face of west abutment of bridge.

DISCHARGE MEASUREMENTS.—Made by wading at low water; from bridge at high water.

CHANNEL AND CONTROL.—One channel, high banks, rocky bottom; no well defined control.

EXTREMES OF DISCHARGE.—Maximum stage recorded during period, 2.80 ft., February 4, 1928 (discharge, 70 second-feet) ; minimum discharge, dry.

DIVERSIONS.—Storm flow only passes this station, the normal flow being diverted above.

ACCURACY.—Stage discharge relation not permanent; shifting control. Rating curve poorly defined. Gage read to hundredths once a week. Record fair. Discharge interpolated between measurements.

Discharge measurements of San Antonio Creek at Power House No. 1 bridge, near Claremont, State Gage Station Index No. 1–3

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—							
February 16	([a])	5.5	3,150.0	February 21	F. W. Bush	0.95	0.4
1928—				April 3	L. Berger	0.98	0.6
January 22	W. S. Post	0	Dry	April 5	L. Berger	0.95	0.6
February 4	W. S. Post	2.8	70.0	April 17	F. W. Bush	0	....

[a] Field cross-section from high water marks by F. W Bush. Computed from Kutter's Formula, by J. A. Case.

Daily discharge in second-feet of San Antonio Creek at Power House No. 1 bridge, near Claremont, State Gage Station Index No. 1–3

For the year ending September 30, 1928

Day	February	March	April	Day	February	March	April
1	0	0.4	0.4	16	0.4	0.4	0.4
2	0	0.4	0.4	17	0.4	0.4	0
3	0	0.4	0.4	18	0.4	0.4	0
4	17.0	0.4	0.4	19	0.4	0.4	0
5	0.4	0.4	0.4	20	0.4	0.4	0
6	0.4	0.4	0.4	21	0.4	0.4	0
7	0.4	0.4	0.4	22	0.4	0.4	0
8	0.4	0.4	0.4	23	0.4	0.4	0
9	0.4	0.4	0.4	24	0.4	0.4	0
10	0.4	0.4	0.4	25	0.4	0.4	0
11	0.4	0.4	0.4	26	0.4	0.4	0
12	0.4	0.4	0.4	27	0.4	0.4	0
13	0.4	0.4	0.4	28	0.4	0.4	0
14	0.4	0.4	0.4	29	0.4	0.4	0
15	0.4	0.4	0.4	30		0.4	0
				31		0.4	

NOTE.—Dry on months for which no discharge is given.

Monthly discharge of San Antonio Creek at Power House No. 1 bridge near Claremont, State Gage Station Index No. 1–3

For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
January	0	0	0	0
February	17.0	0.4	0.93	53.0
March	0.4	0.4	.4	25.0
April	0.4	0	0.07	12.0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
Totals for the year	17.0	0	0.125	90.0

ONTARIO POWER CO.'S DIVERSION FOR POWER HOUSE No. 1 NEAR CLAREMONT, STATE GAGE STATION INDEX No. 1–7

LOCATION.—In SW¼, Sec. 13, T. 1 N., R. 8 W., at Power House No. 1, near Claremont, San Bernardino County.

DRAINAGE AREA.—None.

RECORDS AVAILABLE.—October 1, 1926, to September 30, 1928.

EXTREMES OF DISCHARGE.—Maximum mean daily discharge, 21.0 sec.ft., February 14–16, 1927; minimum discharge, 6.6 sec-ft., September 23, 1928.

ACCURACY.—Daily discharge based on mean of three gage readings daily at power house weir, calibrated with standard weir.

COOPERATION.—Record furnished by Ontario Power Co. and Southern California Edison Co.

Daily discharge in second-feet of Ontario Power Co.'s diversion for Power House No. 1, near Claremont, State Gage Station Index No. 1–7

For the year ending September 30, 1927

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	11.4	9.1	12.2	14.0	14.8	18.1	20.5	19.5	19.0	19.0	16.2	13.1
2	11.4	8.7	11.8	14.0	14.4	18.1	20.5	19.5	19.0	19.0	15.3	12.7
3	11.4	9.1	12.7	14.0	14.4	18.1	20.5	19.5	19.0	19.0	15.7	12.7
4	11.4	9.1	14.0	14.0	15.7	18.5	20.5	19.5	19.0	19.0	15.3	12.2
5	10.6	9.1	15.7	14.4	14.8	18.5	20.5	19.0	19.0	18.5	15.3	12.2
6	11.0	9.1	14.0	14.4	14.8	20.0	20.5	19.0	19.0	18.5	15.3	12.2
7	11.0	8.7	15.7	14.4	14.8	20.0	20.0	19.5	19.0	18.5	14.8	12.7
8	11.0	8.7	16.6	14.0	14.8	20.0	20.0	19.5	19.0	19.0	15.3	12.7
9	11.0	9.1	15.7	14.0	14.8	20.0	20.0	19.5	19.0	19.5	14.8	12.7
10	10.6	8.7	14.8	14.4	14.8	19.5	20.0	19.0	19.0	19.5	14.4	12.7
11	10.6	9.1	14.8	14.4	14.4	20.0	20.0	19.0	19.0	19.5	14.4	12.7
12	10.2	9.1	14.8	14.4	14.4	19.5	20.0	19.0	19.0	19.0	14.4	12.7
13	10.6	9.1	14.8	14.4	14.8	19.5	20.0	19.0	19.0	19.0	14.8	13.1
14	10.2	9.4	14.8	14.4	21.0	20.0	19.5	19.0	18.5	19.0	14.8	13.1
15	10.6	10.2	15.3	14.4	21.0	20.0	19.5	19.0	19.0	19.0	14.8	12.7
16	10.6	9.8	14.8	14.4	21.0	20.0	19.5	19.0	19.0	18.5	14.8	13.1
17	10.6	9.8	14.4	14.8	20.5	20.0	20.0	19.0	18.5	18.1	14.8	12.7
18	10.6	9.8	14.8	14.8	20.0	20.0	20.0	19.0	18.5	18.1	14.8	12.7
19	10.6	9.8	14.8	14.8	19.5	20.0	20.0	19.0	18.5	18.1	14.8	12.7
20	10.6	9.8	14.4	14.8	19.5	20.0	20.0	19.0	18.5	18.5	14.4	12.2
21	9.4	9.8	15.7	15.3	19.0	20.0	20.0	19.0	18.5	17.6	14.8	12.2
22	10.6	10.2	14.8	15.3	19.5	20.0	20.0	19.0	18.5	17.6	14.0	11.4
23	10.6	9.8	14.8	15.3	18.1	20.0	19.5	19.0	18.5	17.6	14.0	12.2
24	10.6	11.8	13.5	15.3	16.6	20.0	19.0	19.0	18.5	17.1	14.0	12.2
25	10.6	10.6	14.4	15.3	15.3	20.0	19.5	19.0	18.5	17.1	14.0	11.8
26	10.2	11.4	14.4	15.3	17.6	20.0	19.5	19.0	18.5	17.1	13.5	11.4
27	9.8	18.1	14.4	15.3	18.1	20.0	19.5	19.0	18.5	17.1	13.5	11.8
28	9.8	14.4	14.4	14.8	19.5	20.0	19.5	19.0	19.0	16.6	13.1	11.8
29	10.2	13.5	14.0	14.8	-------	20.0	19.5	19.0	18.5	16.6	13.1	11.8
30	8.3	13.1	14.0	14.8	-------	20.5	19.5	19.0	19.0	16.2	13.1	12.2
31	9.1	-------	14.0	14.8	-------	20.0	-------	19.0	-------	-------	13.1	-------

Daily discharge in second-feet of Ontario Power Co.'s diversion for Power House No. 1, near Claremont, State Gage Station Index No. 1–7

For the year ending September 30, 1928

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	11.0	11.0	10.6	10.6	10.6	12.0	15.0	13.6	11.3	10.5	8.5	7.3
2	11.4	11.0	10.2	10.6	10.2	12.0	15.2	13.8	11.3	10.2	8.4	7.4
3	11.8	11.0	10.2	10.2	12.2	12.8	16.2	13.8	11.2	10.0	8.6	7.4
4	11.4	10.6	11.4	10.6	20.0	12.5	15.7	13.4	10.8	10.3	8.6	7.6
5	11.8	10.6	10.2	10.2	17.1	12.2	15.4	13.3	10.6	10.0	8.6	7.5
6	11.4	10.6	10.2	10.2	17.1	13.2	15.3	13.6	10.6	9.9	8.3	7.3
7	11.4	10.6	9.8	10.2	15.7	13.2	15.1	13.8	10.4	10.0	8.3	7.3
8	11.4	11.1	9.8	10.2	14.4	13.1	15.1	14.0	10.6	10.1	8.1	8.4
9	11.4	10.6	9.8	10.2	14.4	13.0	15.1	14.9	11.0	9.8	8.0	7.6
10	11.4	11.1	11.4	11.2	13.1	13.0	14.8	14.7	11.0	9.7	8.1	7.5
11	11.0	11.1	10.2	9.8	13.5	13.0	14.6	14.3	11.0	9.5	7.9	7.6
12	11.4	10.6	10.2	10.2	13.5	13.1	14.6	14.5	10.6	9.2	7.8	7.6
13	11.0	11.1	10.2	10.2	13.5	13.2	14.1	14.0	12.0	9.2	7.9	7.3
14	10.6	11.1	10.2	10.6	13.5	13.1	14.0	14.0	11.0	9.3	8.0	7.4
15	11.0	11.1	10.2	10.2	13.5	13.1	13.9	14.3	10.9	9.3	8.0	7.2
16	10.6	11.1	10.2	10.6	13.1	13.4	14.0	14.5	10.8	9.1	7.9	7.3
17	11.0	11.1	10.2	10.2	13.5	13.2	14.0	14.5	10.8	9.2	7.8	6.8
18	10.6	11.1	10.6	10.2	12.7	13.2	14.4	14.0	11.1	9.2	7.5	7.1
19	10.6	11.1	10.2	10.2	13.1	13.1	14.0	13.6	11.1	9.1	7.6	6.8
20	10.6	11.1	10.2	10.2	12.7	13.1	14.3	13.6	11.0	8.8	7.6	6.9
21	10.6	11.1	10.2	10.2	12.2	13.4	14.1	13.4	11.2	9.3	7.7	6.8
22	10.6	11.1	10.2	10.2	12.7	13.8	13.8	13.4	10.8	8.9	7.8	6.9
23	10.2	11.1	10.2	10.2	12.2	14.0	13.8	12.6	10.8	8.8	7.7	6.6
24	10.2	11.1	10.2	10.2	12.2	13.9	13.6	12.4	10.9	8.8	7.8	7.3
25	10.6	10.6	10.6	10.2	11.4	14.1	13.8	12.8	10.5	8.5	7.6	7.0
26	10.6	10.6	12.2	10.6	12.2	14.3	13.4	12.4	10.5	8.5	7.7	7.1
27	11.0	10.6	11.4	10.2	12.2	14.8	13.5	12.4	10.6	8.5	7.6	7.1
28	10.6	10.6	11.4	10.2	12.2	15.0	13.5	12.4	10.7	8.5	7.7	7.1
29	10.6	10.6	11.0	10.2	12.0	14.6	13.1	12.2	10.7	8.1	7.4	7.2
30	10.6	11.0	10.6	10.2	-------	14.9	13.0	11.7	10.2	8.3	7.4	7.2
31	11.8	-------	10.6	10.6	-------	15.0	-------	11.9	-------	8.4	7.6	-------

Monthly discharge of Ontario Power Co.'s diversion for Power House No. 1, near Claremont, State Gage Station Index No. 1–7
For the year ending September 30, 1927

Month, 1926-27	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	11.4	8.3	10.5	645
November	18.1	8.7	10.3	611
December	16.6	11.8	14.5	891
January	15.3	14.0	14.6	900
February	21.0	14.4	17.1	948
March	20.5	18.1	19.7	1,211
April	20.5	19.5	19.9	1,184
May	19.5	19.0	19.1	1,175
June	19.0	18.5	18.8	1,118
July	19.5	16.2	18.2	1,085
August	16.2	13.1	14.5	892
September	13.1	11.4	12.4	763
The year	21.0	8.3	15.9	11,423

Monthly discharge of Ontario Power Co.'s diversion for Power House No. 1, near Claremont, State Gage Station Index No. 1–7
For the year ending September 30, 1928

Month, 1927-28	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	11.8	10.2	11.0	676
November	11.1	10.6	10.9	649
December	12.2	9.8	10.5	646
January	10.6	9.8	10.3	633
February	20.0	11.4	13.3	765
March	15.0	12.0	13.4	824
April	16.2	13.0	14.4	857
May	14.7	11.7	13.5	830
June	12.0	10.2	10.9	649
July	10.5	8.1	9.3	572
August	8.6	7.4	7.9	486
September	8.4	6.6	7.2	428
The year	16.2	6.6	11.0	8,015

CUCAMONGA CANYON NEAR UPLAND, STATE GAGE STATION INDEX No. 2–1

LOCATION.—In NE¼, Sec. 19, T. 1 N., R. 7 W., 4 miles north of Base Line road, near Upland, on line of Saphire Ave. extended north.

DRAINAGE AREA.—10.3 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Water-stage recorder in 12″ corrugated iron pipe on right bank of channel.

DISCHARGE MEASUREMENTS.—Made by wading at low water; from cable at high water.

CHANNEL AND CONTROL.—One channel, high banks, hard rocky bottom; good control.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 3.15 ft., 9 a.m., February 4, (discharge, 72 sec.-ft.); minimum discharge, 1.0 sec.-ft., July 13 and 14.

DIVERSIONS.—None above station.

ACCURACY.—Stage discharge relation not permanent. Rating curve well defined from zero to 72 sec.-ft. Water-stage recorder gave good record from time of installation, January 13, 1928. Daily discharge ascertained by applying mean daily gage height to rating table, except for the period May 18 to September 30, when it was interpolated between measurements. Records good.

Rating table of Cucamonga Canyon near Upland,
State Gage Station Index No. 2-1

Gage height	Discharge second-feet	Gage height	Discharge second-feet
2.20	4.0	3.00	56
2.30	4.8	3.10	67
2.40	7.2	3.20	78
2.50	11.6	3.50	210
2.60	18.0	4.00	590
2.70	26.0	4.50	1,100
2.80	35.0	5.00	1,750
2.90	45.0	5.50	2,500

Discharge measurements of Cucamonga Canyon near Upland,
State Gage Station Index No. 2-1

During year ending September 30, 1928

Date	Made by	Gage height, feet	Discharge, second-feet	Date, 1928	Made by	Gage height, feet	Discharge, second-feet
1927—				April 13	F. W. Bush	2.24	4.8
Feb. 16	[a]	7.7	6120.0	April 20	F. W. Bush	2.23	4.4
1928—				April 27	F. W. Bush	2.21	2.7
Jan. 5	F. W. Bush	2.25	4.0	May 4	F. W. Bush	2.18	1.4
Jan. 13	F. W. Bush	2.24	4.1	May 11	F. W. Bush	2.22	3.1
Jan. 20	F. W. Bush	2.25	4.0	May 18	F. W. Bush	2.20	2.4
Jan. 27	F. W. Bush	2.24	4.0	May 25	F. W. Bush	---------	2.5
Feb. 3	F. W. Bush	2.30	5.1	June 1	F. W. Bush	2.25	2.1
Feb. 4	J. A. Case	3.11	67.4	June 8	F. W. Bush	3.30	2.1
Feb. 4	J. A. Case	2.98	49.9	June 15	F. W. Bush	---------	1.7
Feb. 4	J. A. Case	2.68	23.9	June 22	F. W. Bush	3.32	2.0
Feb. 10	F. W. Bush	2.36	5.7	June 29	F. W. Bush	3.20	1.8
Feb. 17	F. W. Bush	2.31	5.0	July 6	F. W. Bush	3.16	1.6
Feb. 24	F. W. Bush	2.28	5.0	July 13	F. W. Bush	3.06	1.0
Mar. 2	F. W. Bush	2.26	3.4	July 21	F. W. Bush	3.13	1.4
Mar. 9	F. W. Bush	2.29	2.3	July 27	F. W. Bush	---------	1.6
Mar. 16	F. W. Bush	2.27	4.2	Aug. 3	F. W. Bush	---------	1.6
Mar. 23	F. W. Bush	2.27	5.2	Aug. 11	F. W. Bush	---------	1.4
Mar. 30	F. W. Bush	2.28	5.4	Aug. 17	F. W. Bush	---------	1.6
April 6	F. W. Bush	2.26	4.3	Aug. 25	F. W. Bush	---------	1.7
April 11	F. W. Bush	2.25	3.2	Aug. 31	F. W. Bush	---------	1.5

[a] Field cross-section from flood marks made by F. W. Bush. Computed from Kutter's formula by J. A. Case.

Daily discharge in second-feet of Cucamonga Canyon near Upland, State Gage Station Index No. 2–1

For the year ending September 30, 1928

Day	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1	4.2	4.2	4.4	4.4	2.1	2.1	1.8	1.6	1.6
2	4.2	4.2	4.3	4.4	2.3	2.1	1.8	1.6	1.6
3	4.2	4.7	4.8	4.4	2.1	2.1	1.7	1.6	1.6
4	4.2	32.7	4.4	4.4	2.3	2.1	1.7	1.6	1.6
5	4.2	14.2	5.8	4.4	2.0	2.1	1.7	1.6	1.6
6	4.2	8.4	5.8	4.4	2.0	2.1	1.6	1.5	1.6
7	4.2	7.3	5.1	4.2	2.1	2.1	1.6	1.5	1.6
8	4.2	6.8	5.0	4.2	2.7	2.1	1.5	1.5	1.6
9	4.2	6.4	4.7	4.2	4.2	2.1	1.4	1.5	1.6
10	4.1	6.0	4.7	4.2	3.0	2.0	1.3	1.4	1.6
11	4.1	5.8	4.7	4.2	3.0	2.0	1.2	1.4	1.6
12	4.1	5.6	4.7	4.2	3.0	1.9	1.1	1.5	1.6
13	4.1	5.3	4.7	4.2	2.8	1.9	1.0	1.5	1.6
14	4.1	5.0	4.5	4.2	3.0	1.8	1.0	1.5	1.6
15	4.1	5.0	4.5	4.2	3.0	1.7	1.1	1.5	1.6
16	4.1	5.1	4.4	4.1	2.8	1.7	1.1	1.5	1.6
17	4.0	5.0	4.4	4.1	2.7	1.7	1.2	1.6	1.6
18	4.1	5.0	4.3	4.1	2.4	1.8	1.3	1.6	1.6
19	4.2	4.8	4.3	4.1	2.4	1.9	1.4	1.6	1.6
20	4.2	4.7	4.3	4.1	2.4	1.9	1.4	1.6	1.6
21	4.3	4.5	4.3	4.1	2.4	1.9	1.4	1.6	1.6
22	4.3	4.4	4.3	4.1	2.4	2.0	1.4	1.7	1.6
23	4.3	4.4	4.3	4.1	2.4	2.0	1.5	1.7	1.6
24	4.3	4.5	4.7	4.2	2.5	1.9	1.5	1.7	1.6
25	4.3	4.4	4.7	4.2	2.5	1.9	1.5	1.7	1.6
26	4.2	4.3	4.7	4.0	2.5	1.9	1.6	1.6	1.6
27	4.2	4.3	4.8	3.9	2.4	2.0	1.6	1.6	1.6
28	4.2	4.3	4.8	3.9	2.3	2.0	1.6	1.5	1.6
29	4.2	4.3	4.5	3.8	2.3	1.9	1.6	1.5	1.6
30	4.2	-------	4.5	3.8	2.2	1.9	1.6	1.5	1.6
31	4.2	-------	4.4	-------	2.1	-------	1.6	1.5	-------

Monthly discharge of Cucamonga Canyon near Upland, State Gage Station Index No. 2–1

For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				e246
November				e387
December				e258
January	4.3	4.0	4.18	257
February	32.7	4.2	6.40	368
March	5.8	4.3	4.64	285
April	4.4	4.2	4.20	250
May	4.2	2.0	2.52	155
June	2.1	1.9	1.95	116
July	1.8	1.0	1.45	88
August	1.7	1.4	1.56	96
September			1.60	95
The year				2,600

e Estimated.

DEER CREEK NEAR CUCAMONGA, STATE GAGE STATION INDEX No. 3–1

LOCATION.—In SW¼, Sec. 12, T. 1 N., R. 7 W., 4 miles north of Base Line road at end of road near Cucamonga, on line of Haven Ave. extended north.

DRAINAGE AREA.—3.5 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff on right side of channel.

DISCHARGE MEASUREMENTS.—None.

CHANNEL AND CONTROL.—One channel, high banks, rocky bottom; no well-defined control.

EXTREMES OF DISCHARGE.—Dry during entire year.

DIVERSION.—Hermosa Water Company diverts entire flow above gage.

Discharge measurements of Deer Creek near Cucomonga, State Gage Station Index No. 3–1

During year ending September 30, 1928

Date	Made by	Gage height	Discharge second-feet
1927—			
Feb. 16	([a])	8.2	5225
Dec. 27	Bush		Dry
1928—			
Jan. 22	Bush		Dry
Feb. 1	Bush		Dry

[a] Field cross-section from flood marks made by F. W. Bush. Computed from Kutter's formula by J. A. Case.

HERMOSA WATER COMPANY DIVERSION FROM DEER CREEK NEAR CUCAMONGA, STATE GAGE STATION INDEX No. 3–2

LOCATION.—In Sec. 12, T. 1 N., R. 7 W., 4 miles north of Base Line road, near Cucamonga.

DRAINAGE AREA.—None.

RECORD AVAILABLE.—October 1, 1926, to September 30, 1928.

GAGE.—Staff.

DISCHARGE MEASUREMENTS.—From records of Hermosa Water Company.

ACCURACY.—Records based on measurements made by Hermosa Water Company at their intake once a month.

Discharge measurements of diversion of Hermosa Water Co. from Deer Creek near Cucamonga, State Gage Station Index No. 3–2

For the years ending September 30, 1926 and 1927

Date	Made by	Gage height	Discharge second-feet
1926—			
July 6	Hermosa Water Co.		1.0
Aug. 5	Hermosa Water Co.		0.8
Sept. 5	Hermosa Water Co.		0.8
Oct. 2	Hermosa Water Co.		0.8
Nov. 1	Hermosa Water Co.		0.8
Nov. 25	Hermosa Water Co.		0.8
1927—			
May 2	Hermosa Water Co.		1.8
June 6	Hermosa Water Co.		1.8
July 5	Hermosa Water Co.		1.4
Aug. 1	Hermosa Water Co.		1.2
Sept. 5	Hermosa Water Co.		1.2
Oct. 3	Hermosa Water Co.		1.2

Monthly discharge of diversion of Hermosa Water Co. from Deer Creek, State Gage Station Index No. 3–2

For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October			1.1	68
November			1.6	95
December			1.4	86
January			1.3	80
February			1.8	104
March			1.6	98
April			1.1	65
May			0.9	55
June			0.9	54
July			0.8	48
August			0.7	43
September			0.7	42
The year				838

DAY CANYON NEAR ETIWANDA, STATE GAGE STATION INDEX No. 4–1

LOCATION.—In SW¼, Sec. 8, T. 1 N., R. 6 W., 4 miles north of Base Line road, near Etiwanda, on line of Etiwanda avenue extended north.

DRAINAGE AREA.—4.9 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Water-stage recorder 25 ft. upstream from diversion pipe of Etiwanda Water Co.

DISCHARGE MEASUREMENTS.—Made by wading at low water, and from bridge at high water.

CHANNEL AND CONTROL.—One channel, high banks, rocky bottom; good control.

EXTREMES OF DISCHARGE.—Maximum stage recorded during year, 2.48 feet, February 4 (discharge, 29 sec.-ft.); minimum stage, 1.72 ft., April 16–19 (discharge, 0.9 sec. ft.).

DIVERSIONS.—One diversion by Etiwanda Water Co. for spreading one-half mile upstream.

ACCURACY.—Rating curve well defined up to discharge of 30 sec.-ft.; permanent control. Water-stage recorder gave good record from time of installation January 6, 1928. Daily discharge ascertained by applying mean daily gage height to rating table. Records good.

Rating table of Day Canyon near Etiwanda, State Gage Station Index No. 4–1

Gage height	Discharge second-feet	Gage height	Discharge second-feet
1.80	1.3	3.00	140
1.82	1.6	3.50	320
1.84	1.8	4.00	575
1.86	1.9	4.50	900
1.88	2.2	5.00	1,275
1.90	2.3	5.50	1,675
1.95	3.1	6.00	2,080
2.00	4.3	6.50	2,525
2.50	36.0	7.00	2,950

Discharge measurements of Day Canyon near Etiwanda, State Gage Station Index No. 4–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet
1927—			
Feb. 16	(a)	8.5	4,430.0
Sept. 26	*G. Shepherd		2.6
Oct. 3	*G. Shepherd		2.6
Oct. 10	*G. Shepherd		2.5
Oct. 19	*G. Shepherd		2.4
Nov. 28	*G. Shepherd		2.8
1928—			
Jan. 6	F. W. Bush	1.81	1.4
Jan. 14	F. W. Bush	1.76	1.4
Jan. 20	F. W. Bush	1.76	1.1
Jan. 27	F. W. Bush	1.94	2.5
Feb. 3	F. W. Bush	1.78	1.2
Feb. 4	J. A. Case	2.32	18.6
Feb. 10	F. W. Bush	1.85	2.1
Feb. 17	F. W. Bush	1.75	1.4
Feb. 24	F. W. Bush	1.73	1.3
Mar. 2	F. W. Bush	1.79	0.9
Mar. 3	J. A. Case	1.80	1.9
Mar. 3	J. A. Case	1.80	1.9
Mar. 5	J. A. Case	2.02	3.8
Mar. 5	J. A. Case	2.20	6.6
Mar. 5	J. A. Case	1.98	5.1
Mar. 9	F. W. Bush	1.76	1.2
Mar. 16	F. W. Bush	1.74	1.2
Mar. 23	F. W. Bush	1.72	1.0
Mar. 24	J. A. Case	1.87	2.1
Mar. 30	F. W. Bush	1.82	1.9
April 6	F. W. Bush	1.78	1.6
April 11	L. Berger	1.75	1.5
April 13	F. W. Bush	1.72	0.9
April 20	F. W. Bush	1.73	1.0
May 4	F. W. Bush	1.82	1.8
May 11	F. W. Bush	1.94	2.7
May 18	F. W. Bush	1.86	2.1
May 25	F. W. Bush	1.79	1.6
June 1	F. W. Bush	1.78	1.4
June 8	F. W. Bush	1.81	1.7
June 15	F. W. Bush	1.79	1.6
June 23	F. W. Bush	1.80	1.6
June 29	F. W. Bush	1.79	1.6
July 6	F. W. Bush	1.76	1.2
July 13	F. W. Bush	1.71	1.0
July 20	F. W. Bush	1.73	1.2
July 27	F. W. Bush	1.70	1.2
Aug. 4	F. W. Bush	1.78	1.5
Aug. 10	F. W. Bush	1.69	1.2
Aug. 17	F. W. Bush	1.72	1.3
Aug. 25	F. W. Bush	1.73	1.4
Aug. 31	F. W. Bush	1.71	0.4

* Employee of Etiwanda Water Co.

a Field cross-section from high water marks by F. W. Bush. Computed from Kutter's formula by J. A. Case.

Daily discharge in second-feet of Day Canyon near Etiwanda, State Gage Station Index No. 4–1

For the year ending September 30, 1928

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1	2.6	2.5		1.2	1.6	1.0	1.3	1.2	1.4	1.7	1.3	1.3
2	2.6	2.6		1.2	1.1	0.9	1.3	1.4	1.8	1.4	1.4	1.3
3	2.6	2.6		1.2	1.2	1.2	2.3	1.4	1.8	1.4	1.5	1.3
4	2.6	2.6		1.3	17.4	1.1	1.8	1.8	1.7	1.1	1.4	1.3
5	2.6	2.6		1.3	8.7	3.1	1.6	1.9	1.6	1.1	1.3	1.3
6	2.6	2.6		1.4	4.8	2.0	1.3	2.0	1.4	1.2	1.2	1.3
7	2.6	2.6		1.6	3.1	1.3	1.2	2.1	1.6	1.1	1.2	1.3
8	2.6	2.6		1.8	2.7	1.1	1.1	2.8	1.7	1.1	1.2	1.3
9	2.6	2.6		1.6	2.3	1.1	1.1	5.0	1.6	1.1	1.2	1.3
10	2.6	2.6		1.6	1.9	1.1	1.1	3.3	1.8	1.0	1.2	1.3
11	2.6	2.6		1.2	1.6	1.1	1.1	3.0	2.0	1.0	1.2	1.3
12	2.5	2.6		1.1	1.4	1.1	1.1	2.9	2.0	1.0	1.2	1.3
13	2.5	2.6		1.1	1.3	1.1	0.9	2.8	1.9	1.0	1.2	1.3
14	2.5	2.6		1.1	1.2	1.1	0.9	2.9	1.6	1.0	1.2	1.3
15	2.5	2.6		1.1	1.2	1.1	1.0	3.2	1.7	1.0	1.2	1.3
16	2.5	2.6		1.1	1.1	1.1	0.9	3.0	1.5	1.1	1.2	1.3
17	2.4	2.6		1.1	1.1	1.0	0.9	2.8	1.5	1.1	1.3	1.3
18	2.4	2.7		1.1	1.0	1.0	0.9	2.6	1.8	1.1	1.3	1.3
19	2.4	2.7		1.1	1.0	1.0	0.9	2.5	2.1	1.2	1.3	1.3
20	2.4	2.7		1.1	1.0	0.9	1.0	2.3	1.9	1.2	1.3	1.3
21	2.4	2.7		1.1	1.0	0.9	1.0	2.2	1.8	1.2	1.3	1.3
22	2.4	2.7		1.1	1.0	0.9	1.0	2.0	1.8	1.2	1.3	1.3
23	2.4	2.7		1.1	1.0	0.9	1.0	1.9	1.7	1.2	1.4	1.3
24	2.4	2.7		1.1	1.0	2.1	1.0	1.7	1.6	1.2	1.4	1.3
25	2.4	2.7		1.1	1.0	3.1	1.0	1.6	1.6	1.2	1.4	1.3
26	2.4	2.7		1.1	1.0	2.7	1.0	1.6	1.6	1.2	1.4	1.3
27	2.5	2.8		2.0	1.0	3.3	0.9	1.6	1.6	1.2	1.4	1.3
28	2.5	2.8		2.8	0.9	2.7	0.9	1.5	1.6	1.2	1.3	1.3
29	2.5	2.8		2.8	0.9	2.0	0.9	1.5	1.6	1.2	1.3	1.3
30	2.5	2.8		2.9		1.6	1.0	1.5	1.6	1.2	1.3	1.3
31	2.5			2.9		1.6		1.4		1.2	1.3	

Monthly discharge of Day Canyon near Etiwanda, State Gage Station Index No. 4–1
For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	2.6	2.4	2.50	154
November	2.8	2.5	2.65	158
December			[e]2.00	[e]123
January	2.9	1.1	1.45	89
February	17.4	0.9	2.26	130
March	3.3	0.9	1.51	93
April	2.3	0.9	1.11	66
May	5.0	1.4	2.24	138
June	2.1	1.4	1.70	101
July	1.7	1.0	1.16	71
August	1.5	1.2	1.29	79
September			1.30	77
The year	17.4	0.9	1.76	1,280

[e] Estimated.

ETIWANDA WATER COMPANY DIVERSION FOR SPREADING FROM DAY CANYON NEAR ETIWANDA, STATE GAGE STATION INDEX No. 4–3

LOCATION.—In SW¼, Sec. 9, T. 1 N., R. 6 W., 4 miles north of Baseline road near Etiwanda.

DRAINAGE AREA.—None.

RECORDS AVAILABDE.—January 5 to September 30, 1928.

GAGE.—Staff.

DISCHARGE MEASUREMENTS.—Obtained by measuring depth over weir.

CONTROL.—50″ rectangular weir with end contractions.

EXTREMES OF DISCHARGE.—Maximum discharge, 2.1 sec.-ft., March 28, 1928; minimum discharge, dry.

ACCURACY.—Rating curve well defined, permanent control. Velocity of approach, none. Good stilling chamber. Daily discharge ascertained by interpolation between weir readings taken once a week.

COOPERATION.—Etiwanda Water Company.

Rating table of Etiwanda Water Company fifty-inch rectangular weir with end contractions, diversion for spreading from Day Canyon, State Gage Station Index No. 4–3

Gage height	Discharge second-feet	Gage height	Discharge second-feet
0.00	0.0	0.16	0.9
0.04	0.1	0.18	1.0
0.06	0.2	0.19	1.1
0.08	0.3	0.20	1.2
0.10	0.4	0.21	1.3
0.11	0.5	0.23	1.4
0.13	0.6	0.24	1.6
0.14	0.7	0.25	1.7
0.15	0.8	0.26	1.8

Discharge determination of Etiwanda Water Company fifty-inch rectangular weir with end contractions, diversion for spreading, from Day Canyon, State Gage Station Index No. 4–3

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1928—							
Jan. 5	*G. Shepherd	.21	1 3	Mar. 23	F. W. Bush	.21	1 3
Jan. 12	G. Shepherd	.21	1 3	Mar. 26	F. W. Bush	.26	1 8
Feb. 20	G. Shepherd	.24	1 5	Mar. 28	*G. Shepherd	.29	2 1
Feb. 29	L. Berger	.18	1 0	Mar. 30	F. W. Bush	.22	1 4
Mar. 1	*G. Shepherd	21	1 3	April 2	*G. Shepherd	.24	1 6
Mar. 6	L. Berger	.24	1.5	April 7	F. W. Bush	22	1.4
Mar. 9	F. W. Bush	22	1 4	April 9	*G. Shepherd	24	1.5
Mar. 12	L. Berger	20	1 2	April 13	F. W. Bush	.20	1.2
Mar. 12	*G. Shepherd	24	1 5	April 20	F. W. Bush	.20	1 2
Mar. 16	F. W. Bush	21	1.3	April 27	F. W. Bush	.18	1 0
Mar. 19	*G. Shepherd	21	1.3	May 1	*G. Shepherd	0	0
Mar. 20	L. Berger	.18	1.0	May 4	F. W. Bush	0	0

* Employee of Etiwanda Water Co.

Daily discharge in second-feet of Etiwanda Water Company diversion for spreading from Day Canyon, State Gage Station Index No. 4–3

For the year ending September 30, 1928

Day	Jan.	Feb.	Mar.	April	Day	Jan.	Feb.	Mar.	April
1	1 3	1.3	1.3	1.5	17	1.3	1.5	1 3	1.2
2	1.3	1.3	1.3	1.6	18	1.3	1.5	1 3	1.2
3	1.3	1.4	1.4	1.6	19	1.3	1 5	1.3	1.2
4	1 3	1 4	1 4	1.5	20	1.3	1.5	1.0	1.2
5	1.3	1 4	1 4	1.5	21	1.3	1.4	1.1	1.2
6	1.3	1 4	1 5	1.4	22	1.3	1.3	1 2	1 2
7	1 3	1 4	1.5	1.4	23	1.3	1.2	1.3	1.1
8	1.3	1.4	1.4	1.5	24	1.3	1 0	1.4	1.1
9	1.3	1 5	1 4	1.5	25	1.3	1.0	1 6	1.1
10	1 3	1.5	1.4	1 5	26	1.3	1.0	1.8	1.0
11	1.3	1 5	1 4	1.4	27	1 3	1.1	1.9	1 0
12	1 3	1 5	1 4	1 3	28	1.3	1.1	2 1	1.0
13	1 3	1 5	1.4	1 2	29	1.3	1 2	1.5	1.0
14	1 3	1 5	1 4	1 2	30	1.3		1 4	1.0
15	1 3	1 5	1.3	1.2	31	1.3		1.4	
16	1 3	1 5	1 3	1 2					

Monthly discharge of Etiwanda Water Company diversion for spreading from Day Canyon, State Gage Station Index No. 4–3

For the year ending September 30, 1928

Month, 1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
January	1.3	1.3	1.3	80
February	1.5	1 0	1 35	78
March	2 1	1 0	1 41	87
April	1 6	1.0	1 26	75
The year	2 1	1.0	1 33	320

NOTE—No diversion in October, November, December, May, June, July, August, September.

EAST ETIWANDA CREEK NEAR ETIWANDA, STATE GAGE STATION INDEX No. 5-1

Location.—In SW¼, Sec. 9, T. 1 N., R. 6 W., 4 miles north of Base Line road, near Etiwanda.

Drainage area.—2.9 square miles (measured on topographic map).

Records available.—October 1, 1927, to September 30, 1928.

Gage.—Staff gage 50 ft. upstream from diversion of Etiwanda Water Company.

Discharge measurements.—Made by wading.

Channel and control.—One channel, high banks, rocky bottom; good control.

Extremes of discharge.—Maximum stage recorded during year, 2.36 feet February 4 (discharge, 15.5 sec.-ft.) ; minimum discharge, 0.2 sec. ft., August 10.

Diversions.—None.

Accuracy.—Rating curve well defined. Gage height read once a week, except during storms, when it was read more often. Daily discharge ascertained by applying gage height to rating table and interpolating for days on which the gage was not read. Record fair.

Rating table of East Etiwanda Creek near Etiwanda
State Gage Station Index No. 5-1

Gage height	Discharge second-feet	Gage height	Discharge second-feet
1.50	0.3	1.90	4.2
1.60	0.6	2.00	6.3
1.70	1.3	2.50	19.5
1.80	2.6		

Discharge measurements of East Etiwanda Creek near Etiwanda,
State Gage Station Index No. 5-1
For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				June 8	F. W. Bush	1.64	.9
Feb. 16	[a]	5.1	2840.0	June 15	F. W. Bush	1.60	.7
1928—				June 23	F. W. Bush	1.62	.7
Feb. 9	F. W. Bush	1.72	1.6	June 29	F. W. Bush	1.58	.6
Mar. 24	J. A. Case	1.82	3.1	July 6	F. W. Bush	1.57	.5
Mar. 27	F. W. Bush	1.97	5.7	July 13	F. W. Bush	1.47	.3
April 3	L. Berger	1.90	3.5	July 20	F. W. Bush	1.50	.3
April 20	F. W. Bush	1.72	1.2	July 27	F. W. Bush	1.47	.3
April 27	F. W. Bush	1.66	.9	Aug. 5	F. W. Bush	1.50	.3
May 4	F. W. Bush	1.61	.7	Aug. 10	F. W. Bush	1.46	.2
May 18	F. W. Bush	1.65	.9	Aug. 17	F. W. Bush	1.47	.3
May 25	F. W. Bush	1.59	.6	Aug. 25	F. W. Bush	1.48	.3
June 1	F. W. Bush	1.58	.6	Aug. 31	F. W. Bush	1.47	.3

[a] Field cross-section from flood marks by F. W. Bush. Computed from Kutter's formula by J. A. Case.

Daily discharge in second-feet of East Etiwanda Creek near Etiwanda, State Gage Station Index No. 5-1

For the year ending September 30, 1928

Day	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1	1.5	1.0	3.0	0.7	0.6	0.6	0.3	0.3
2	1.5	1.0	3.0	0.7	0.6	.6	.3	.3
3	1.5	1.5	4.7	0.7	0.7	.5	.3	.3
4	5.0	1.7	3.0	0.7	0.7	.5	.3	.3
5	4.0	2.0	2.0	0.7	0.7	.5	.3	.3
6	3.0	4.0	2.0	0.7	0.8	.5	.3	.3
7	2.0	3.0	1.9	0.7	0.9	.5	.3	.3
8	1.8	1.7	1.9	0.7	0.9	.4	.3	.3
9	1.6	1.7	1.9	0.7	0.9	.4	.3	.3
10	1.6	1.7	1.8	0.7	0.9	.3	.2	.3
11	1.6	1.7	1.8	0.6	0.8	.3	.3	.3
12	1.5	1.7	1.8	0.6	0.8	.3	.3	.3
13	1.5	1.7	1.7	0.6	0.7	.3	.3	.3
14	1.4	1.6	1.7	0.7	0.7	.3	.3	.3
15	1.4	1.6	1.7	0.6	0.7	.3	.3	.3
16	1.3	1.5	1.7	0.6	0.7	.3	.3	.3
17	1.3	1.5	1.6	0.7	0.7	.3	.3	.3
18	1.1	1.4	1.6	0.7	0.7	.3	.3	.3
19	1.1	1.4	1.6	0.7	0.7	.3	.3	.3
20	1.0	1.3	1.5	0.6	0.7	.3	.3	.3
21	1.0	1.5	1.5	0.6	0.7	.3	.3	.3
22	1.0	1.6	1.4	0.6	0.7	.3	.3	.3
23	1.0	1.7	1.3	0.6	0.7	.3	.3	.3
24	1.0	2.8	1.2	0.6	0.7	.3	.3	.3
25	1.0	3.0	1.1	0.6	0.7	.3	.3	.3
26	1.0	4.8	1.0	0.6	0.6	.3	.3	.3
27	1.0	5.7	0.9	0.6	0.6	.3	.3	.3
28	1.0	3.0	0.8	0.6	0.6	.3	.3	.3
29	1.0	3.0	0.8	0.6	0.6	.3	.3	.3
30	-------	2.8	0.8	0.6	0.6	.3	.3	.3
31	-------	2.8	-------	0.6	-------	.3	.3	-------

Monthly discharge of East Etiwanda Creek near Etiwanda, State Gage Station Index No. 5-1

For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	------------	------------	[e] 0.9	[e] 55
November	------------	------------	[e] 1.73	[e] 103
December	------------	------------	[e] 2.0	[e] 123
January	------------	------------	[e] 1.5	[e] 98
February	5.0	1.0	1.58	91
March	5.7	1.0	2.17	133
April	4.7	0.8	1.76	105
May	0.7	0.6	0.65	40
June	0.9	0.6	0.71	42
July	0.6	0.3	0.36	22
August	0.3	0.2	0.30	18
September	------------	------------	0.30	18
The year	5.7	0.2	1.16	848

[e] Estimated.

INGVALDSEN CANYON NEAR FONTANA, STATE GAGE STATION INDEX NUMBER 6–1

LOCATION.—In SW¼, Sec. 15, T. 1 N., R. 6 W., 3.5 miles north of Base Line road, 1¼ miles east of Etiwanda Avenue, near Fontana.

DRAINAGE AREA.—1.1 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on right bank of channel.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel, hard rocky bottom; good control.

EXTREMES OF DISCHARGE.—Maximum stage recorded during period, 1.65 ft., February 4 (discharge 7.0 sec-ft.); minimum discharge, dry.

DIVERSIONS.—None.

ACCURACY.—Rating curve well defined. Gage read once a week. Daily discharge ascertained by applying gage height to rating table and interpolating for days on which the gage was not read. Record fair.

Rating table of Ingvaldsen Canyon, Near Fontana, State Gage Station Index No. 6–1

Gage height	Discharge second-feet	Gage height	Discharge second-feet
1.30	.1	1.80	21.8
1.40	.4	1.90	40.0
1.50	.8	2.00	75.0
1.60	4.0	2.50	315.0
1.70	10.6	3.00	635.0

Discharge measurements of Ingvaldsen Canyon near Fontana, State Gage Station Index No. 6–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Mar. 9	F. W. Bush	1.38	.4
Feb. 16	([a])	3.2	765.0	April 3	L. Berger	1.43	.4
Dec. 28	L. J. Alexander	1.39	.2	April 18	F. W. Bush	1.32	.2
1928—				May 4	F. W. Bush	1.31	.2
Jan. 7	F. W. Bush	1.36	.3	May 15	F. W. Bush	1.30	.2
Jan. 21	F. W. Bush	1.36	.3	June 1	F. W. Bush	1.28	.1
Feb. 1	F. W. Bush	1.36	.3	June 7	F. W. Bush	1.27	.1
Feb. 4	F. W. Bush	1.65	7.0	June 14	F. W. Bush	1.25	.1
Feb. 9	F. W. Bush	1.41	.6	June 29	F. W. Bush		.1
Feb. 16	F. W. Bush	1.39	.4	July 12	F. W. Bush		.3
Feb. 23	F. W. Bush	1.38	.4	July 18	F. W. Bush		dry
Feb. 29	F. W. Bush	1.36	.3	July 26	F. W. Bush		dry
Mar. 2	F. W. Bush	1.34	.3				

[a] Field cross-section from high water marks by F. W. Bush. Computed from Kutter's Formula by J. A. Case.

Daily discharge in second-feet of Ingvaldsen Canyon near Fontana, State Gage Station Index No. 6–1

For the year ending September 30, 1928

Day	Dec.	Jan.	Feb.	Mar.	April	May	June	July
1	--------	0.3	0.3	0.3	0.3	0.2	0.1	0.1
2	--------	0.3	0.3	0.3	0.4	0.2	0.1	0.1
3	--------	0.3	0.3	0.3	0.3	0.2	0.1	0.1
4	--------	0.3	4.0	0.3	0.3	0.2	0.1	0.1
5	--------	0.3	2.0	0.3	0.3	0.2	0.1	0.1
6	--------	0.3	0.8	0.3	0.3	0.2	0.1	0.1
7	--------	0.3	0.7	0.3	0.3	0.2	9.1	0.1
8	--------	0.3	0.6	0.3	0.3	0.2	0.1	0.1
9	--------	0.3	0.6	0.3	0.3	0.2	0.1	0.1
10	--------	0.3	0.6	0.3	0.3	0.2	0.1	0.1
11	--------	0.3	0.5	0.3	0.3	0.2	0.1	0.1
12	--------	0.3	0.5	0.3	0.3	0.2	0.1	0
13	--------	0.3	0.4	0.3	0.3	0.2	0.1	0
14	--------	0.3	0.4	0.3	0.3	0.2	0.1	0
15	--------	0.3	0.4	0.3	0.3	0.2	0.1	0
16	--------	0.3	0.4	0.3	0.3	0.2	0.1	0
17	--------	0.3	0.4	0.3	0.3	0.2	0.1	0
18	--------	0.3	0.4	0.3	0.2	0.2	0.1	0
19	--------	0.3	0.4	0.3	0.2	0.2	0.1	0
20	--------	0.3	0.4	0.3	0.2	9.2	0.1	0
21	--------	0.3	0.4	0.3	0.2	0.2	0.1	0
22	--------	0.3	0.4	0.3	0.2	0.2	0.1	0
23	--------	0.3	0.4	0.3	0.2	0.2	0.1	0
24	--------	0.3	0.4	0.3	0.2	0.2	0.1	0
25	--------	0.3	0.4	0.3	0.2	0.2	0.1	0
26	--------	0.3	0.3	0.3	0.2	0.2	0.1	0
27	--------	0.3	0.3	0.3	0.2	0.2	0.1	0
28	0.2	0.3	0.3	0.3	0.2	0.2	0.1	0
29	0.2	0.3	0.3	0.3	0.2	0.2	0.1	0
30	0.2	0.3	--------	0.3	0.2	0.2	0.1	0
31	0.2	0.3	--------	0.3	--------	0.2	--------	0

Monthly discharge of Ingvaldsen Canyon near Fontana, State Gage Station Index No. 6–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	----------	----------	----------	[e]10
November	----------	----------	----------	[e]20
December	----------	----------	----------	[e]20
January	0.3	0.3	0.30	18
February	4.0	0.3	0.60	35
March	0.3	0.3	0.30	18
April	0.3	0.2	0.26	16
May	0.2	0.2	0.20	12
June	0.1	0.1	0.10	6
July	0.1	0	0.04	2.2
August	0	0	0	0
September	0	0	0	0
The year	4.0	0	0.218	158

[e] Estimated.

SAN SEVAINE CANYON NEAR FONTANA, STATE GAGE STATION INDEX No. 7–1

Location.—In NW¼, Sec. 14, T. 1 N., R. 6 W., 4 miles north of Base Line road at Bullock's ranch, 2 miles east of Etiwanda avenue, near Fontana.

Drainage area.—1.8 square miles (measured on topographic map).

Records available.—October 1, 1927, to September 30, 1928.

Gage.—Staff gage on right bank of channel.

Discharge measurements.—Made by wading.

Channel and control.—One channel; shifting control.

Extremes of discharge.—Maximum discharge recorded, 2.0 sec.-ft., February 4; minimum discharge, 0.3 sec.-ft., July 15 to September 25.

Diversions.—None.

Accuracy.—Rating curve very poorly defined. Gage read once a week. Daily discharge ascertained by applying gage height to rating table and interpolated for days on which the gage was not read. Record fair.

Rating table of San Sevaine Canyon near Fontana, State Gage Station Index No. 7–1

Gage height	Discharge second-feet	Gage height	Discharge second-feet	Gage height	Discharge second-feet
1.65	0.7	1.85	2.0	3.50	450
1.70	0.8	2.00	20.0	4.00	700
1.75	0.9	2.50	100.0	4.50	975
1.80	1.1	3.00	250.0	5.00	1,300

Discharge measurements of San Sevaine Canyon near Fontana, State Gage Station Index No. 7–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				May 4	F. W. Bush	1.65	.7
Feb. 16	[a]	7.0	2,540.0	May 15	F. W. Bush	1.70	1.0
Dec. 29	F. W. Bush	1.81	1.0	May 31	F. W. Bush	1.65	.7
1928—				June 7	F. W. Bush	1.67	.7
Jan. 7	L. J. Alexander	1.81	1.0	June 14	F. W. Bush	1.63	.6
Feb. 2	F. W. Bush	1.76	1.0	June 28	F. W. Bush	1.60	.5
Feb. 7	F. W. Bush	1.81	1.2	July 5	F. W. Bush	1.58	.5
Feb. 14	L. Berger	1.71	1.0	July 12	F. W. Bush	1.56	.4
Feb. 20	L. Berger	1.70	.7	July 18	F. W. Bush	1.54	.3
Feb. 28	L. Berger	1.69	.9	July 25	F. W. Bush	1.52	.3
Mar. 30	L. Berger	1.84	1.5	Aug. 3	F. W. Bush	1.54	.3
April 3	L. Berger	1.85	2.0	Aug. 10	F. W. Bush	1.53	.3
April 11	L. Berger	1.77	1.5	Aug. 17	F. W. Bush	1.52	.3
April 18	F. W. Bush	1.71	1.1	Aug. 31	F. W. Bush	1.52	.3

[a] Cross-section from highwater marks by F. W. Bush. Computed from Kutter's Formula by J. A. Case.

Daily discharge in second-feet of San Sevaine Canyon near Fontana, State Gage Station Index No. 7–1

For the year ending September 30, 1928

Day	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1	--------	1.0	1.0	.9	1.0	.9	.7	.5	.3	.3
2	--------	1.0	1.0	.9	.9	.8	.7	.5	.3	.3
3	--------	1.0	1.0	.9	1.4	.8	.7	.4	.3	.3
4	--------	1.0	2.0	1.0	1.4	.7	.7	.4	.3	.3
5	--------	1.0	1.0	1.1	1.3	.7	.7	.4	.3	.3
6	--------	1.0	.9	1.2	1.3	.7	.7	.4	.3	.3
7	--------	1.0	1.2	1.3	1.3	.7	.7	.4	.3	.3
8	--------	1.0	1.1	1.3	1.3	.7	.7	.4	.3	.3
9	--------	1.0	1.1	1.3	1.3	.7	.7	.4	.3	.3
10	--------	1.0	1.0	1.3	1.2	.8	.7	.4	.3	.3
11	--------	1.0	1.0	1.3	1.2	.8	.6	.4	.3	.3
12	--------	1.0	1.0	1.2	1.2	.8	.6	.4	.3	.3
13	--------	1.0	.9	1.2	1.2	.8	.6	.4	.3	.3
14	--------	1.0	.9	1.2	1.2	.8	.6	.4	.3	.3
15	--------	1.0	.9	1.2	1.2	1.0	.6	.3	.3	.3
16	--------	1.0	.9	1.2	1.1	.9	.6	.3	.3	.3
17	--------	1.0	.9	1.2	1.1	.9	.6	.3	.3	.3
18	--------	1.0	.9	1.1	1.1	.9	.6	.3	.3	.3
19	--------	1.0	.9	1.1	1.1	.8	.6	.3	.3	.3
20	--------	1.0	.9	1.0	1.0	.8	.6	.3	.3	.3
21	--------	1.0	.9	.9	1.0	.8	.5	.3	.3	.3
22	--------	1.0	.9	1.0	1.0	.8	.5	.3	.3	.3
23	--------	1.0	.9	1.1	1.0	.8	.5	.3	.3	.3
24	--------	1.0	.9	1.2	.9	.7	.5	.3	.3	.3
25	--------	1.0	.9	1.2	.9	.7	.5	.3	.3	.3
26	--------	1.0	.9	1.2	.9	.7	.5	.3	.3	.4
27	--------	1.0	.9	1.2	.9	.7	.5	.3	.3	.4
28	--------	1.0	.9	1.2	.9	.7	.5	.3	.3	.4
29	1.0	1.0	.9	1.2	.9	.7	.5	.3	.3	.4
30	1.0	1.0	--------	1.4	.9	.7	.5	.3	.3	.4
31	1.0	1.0	--------	1.3	--------	.7	--------	.3	.3	--------

Monthly discharge of San Sevaine Canyon near Fontana, State Gage Station Index No. 7–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	------------	------------	------------	[e]20
November	------------	------------	------------	[e]53
December	------------	------------	------------	[e]61
January	1.0	1.0	1.0	61
February	2.0	.9	1.02	59
March	1.4	.9	1.15	71
April	1.4	.9	1.10	65
May	1.0	.7	.77	48
June	.7	.5	.60	36
July	.5	.3	.35	22
August	.3	.3	.30	18
September	.4	.3	.32	19
The year	2.0	.3	.72	524

[e] Estimated.

HAWKER CANYON NEAR FONTANA, STATE GAGE STATION INDEX No. 8–1

LOCATION.—In NE¼, Sec. 15, T. 1 N., R. 6 W., 3⅝ miles north of Base Line road, 2½ miles west of Citrus avenue, near Fontana.

DRAINAGE AREA.—0.5 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage at diversion dam.

DISCHARGE MEASUREMENTS.—Obtained by measuring depth of water over 10″ rectangular weir with end contractions.

CHANNEL AND CONTROL.—One channel.

EXTREMES OF DISCHARGE.—No record.

ACCURACY.—No rating curve obtainable, as the season of 1927–1928 did not have sufficient water. Gage height read once a week. Daily discharge ascertained by applying gage height to weir table and by interpolation on days for which the gage was not read.

Discharge measurements of Hawker Canyon near Fontana, State Gage Station Index No. 8–1

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				April 2	L. Berger	.15	.10
Feb. 16	[a]	2.6	370.0	April 3	L. Berger	.18	.20
Dec. 29	L. J. Alexander	.15	.1	April 18	F. W. Bush	.15	.10
1928—				April 27	F. W. Bush	.15	.10
Feb. 7	F. W. Bush	.21	.2	May 4	F. W. Bush	.15	.10
Feb. 14	F. W. Bush	.15	.1	May 15	F. W. Bush	.13	.10
Feb. 20	F. W. Bush	.10	.1	June 7	F. W. Bush	.12	.10
Feb. 28	F. W. Bush	.10	.1	June 14	F. W. Bush	.12	.10
Mar. 3	F. W. Bush	.12	.1	June 28	F. W. Bush	.10	.10
Mar. 7	L. Berger	.12	.1	July 12	F. W. Bush	.09	.05
Mar. 9	L. Berger	.12	.1	July 18	F. W. Bush	.08	.02
Mar. 13	L. Berger	.12	.1	July 25	F. W. Bush	.08	.02
Mar. 16	L. Berger	.11	.1	Aug. 3	F. W. Bush	.08	.02
Mar. 21	L. Berger	.11	.1	Aug. 10	F. W. Bush	.08	.02
Mar. 23	L. Berger	.15	.1	Aug. 17	F. W. Bush	.08	.02
Mar. 24	L. Berger	.18	.2	Aug. 31	F. W. Bush	.08	.02
Mar. 30	L. Berger	.15	.1				

[a] Field cross-sections from high water marks by F. W. Bush. Computed from Kutter's Formula, by J. A. Case.

Daily discharge in second-feet of Hawker Canyon near Fontana, State Gage Station Index No. 8–1

For the year ending September 30, 1928

Day	Jan.	Feb.	Mar.	April	May	June	July
1	.1	.1	.1	.1	.1	.1	.1
2	.1	.1	.1	.1	.1	.1	.1
3	.1	.1	.1	.1	.1	.1	.1
4	.1	1.0	.1	.1	.1	.1	.1
5	.1	.5	.1	.1	.1	.1	.1
6	.1	.4	.1	.1	.1	.1	.1
7	.1	.3	.1	.1	.1	.1	.1
8	.1	.3	.1	.1	.1	.1	.1
9	.1	.2	.1	.1	.1	.1	.1
10	.1	.1	.1	.1	.1	.1	.1
11	.1	.1	.1	.1	.1	.1	.1
12	.1	.1	.1	.1	.1	.1	0
13	.1	.1	.1	.1	.1	.1	0
14	.1	.1	.1	.1	.1	.1	0
15	.1	.1	.1	.1	.1	.1	0
16	.1	.1	.1	.1	.1	.1	0
17	.1	.1	.1	.1	.1	.1	0
18	.1	.1	.1	.1	.1	.1	0
19	.1	.1	.1	.1	.1	.1	0
20	.1	.1	.1	.1	.1	.1	0
21	.1	.1	.1	.1	.1	.1	0
22	.1	.1	.1	.1	.1	.1	0
23	.1	.1	.1	.1	.1	.1	0
24	.1	.1	.1	.1	.1	.1	0
25	.1	.1	.1	.1	.1	.1	0
26	.1	.1	.1	.1	.1	.1	0
27	.1	.1	.1	.1	.1	.1	0
28	.1	.1	.1	.1	.1	.1	0
29	.1	.1	.1	.1	.1	.1	0
30	.1	----------	.1	.1	.1	.1	0
31	.1	----------	.1	----------	.1	----------	0

Note—Dry during August and September.

Monthly discharge of Hawker Canyon near Fontana, State Gage Station Index No. 8–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	----------	----------	----------	0
November	----------	----------	----------	[e]4
December	----------	----------	----------	[e]6
January	.1	.1	.1	6
February	1.0	.1	.1	7
March	.1	.1	.1	6
April	.1	.1	.1	6
May	.1	.1	.1	6
June	.1	.1	.1	6
July	.1	0	.04	2
August	0	0	0	0
September	0	0	0	0
The year	1.0	0	.06	49

[e] Estimated.

HOWARD CANYON AT GETCHEL PLACE, NEAR FONTANA, STATE GAGE INDEX NO. 9-1

LOCATION.—In NE¼, Sec. 18, T. 1 N., R. 5 W., 3¾ miles north of Base Line road, ½ mile east of Citrus avenue, near Fontana, known as Crawford Canyon, also locally as Duncan Canyon.

DRAINAGE AREA.—0.7 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928. Data supplied by Boaz Duncan.

GAGE.—Staff gage.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—Rocky, coarse gravel, some brush. Control not permanent for large discharge.

DIVERSION.—None.

EXTREMES OF DISCHARGE.—Constant flow of 10 miner's inches. Discharge is not affected by moderate storms.

COOPERATION.—Boaz Duncan, owner of ranch using water from this canyon.

Discharge measurements of Howard Canyon at Getchel Place, near Fontana, State Gage Station Index No. 9-1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927— Feb. 16	a	4.40	925.0	1928— May 15	F. W. Bush		0.2

[a] Field cross-sections from high water marks by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

NOTE—Boaz Duncan, owner of ranch using water from this canyon states that there is a constant flow of 0.2 second-feet. Moderate storms do not effect the discharge.

Monthly discharge of Howard Canyon at Getchel Place, near Fontana, State Gage Station Index No. 9-1

For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October			.2	12
November			.2	12
December			.2	12
January			.2	12
February			.2	12
March			.2	12
April			.2	12
May			.2	12
June			.2	12
July			.2	12
August			.2	12
September			.2	12
The year			.2	144

LYTLE CREEK AT SANTA FE RAILROAD BRIDGE, NEAR RIALTO, STATE GAGE STATION INDEX No. 10–5

LOCATION.—On the bridge of the Atchison, Topeka and Santa Fe Railroad crossing of Lytle Creek near Rialto.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Water-stage recorder on west end of railroad bridge.

DISCHARGE MEASUREMENTS.—Made by wading at low water; from bridge at high water.

CHANNEL AND CONTROL—Control, sandy bottom, not permanent.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 2.8 ft., February 4, 1928 (discharge, 2.0 sec.-ft.); minimum discharge, dry.

ACCURACY.—Water stage recorder did not give satisfactory record. Discharge estimated on February 4, 1928.

Discharge measurements of Lytle Creek at Santa Fe Bridge near Rialto, State Gage Station Index No. 10–5

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Mar. 1	L. Berger	0	0
Feb. 16	[a]	5.2	1,600.0	Mar. 3	L. Berger	0	0
1928—				Mar. 5	L. Berger	0	0
Feb. 4	W. S. Post	0	0	Mar. 8	L. Berger	0	0
Feb. 4	W. S. Post	2.8	2.0	Mar. 13	L. Berger	0	0
Feb. 4	W. S. Post	0	0	Mar. 15	L. Berger	0	0
Feb. 4	W. S. Post	0	0	Mar. 22	L. Berger	0	0
Feb. 18	L. Berger	0	0	Mar. 30	L. Berger	0	0
Feb. 20	L. Berger	0	0	April 5	L. Berger	0	0
Feb. 23	L. Berger	0	0	April 10	L. Berger	0	0
Feb. 28	L. Berger	0	0	May 9	L. Berger	0	0

[a] Field cross-sections from high water marks by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Daily discharge in second-feet of Lytle Creek at Santa Fe Railroad Bridge, near Rialto, State Gage Station Index No. 10–5

For the year ending September 30, 1928

Day	Feb.	Day	Feb.	Day	Feb.
1	0	11	0	21	0
2	0	12	0	22	0
3	0	13	0	23	0
4	.2	14	0	24	0
5	0	15	0	25	0
6	0	16	0	26	0
7	0	17	0	27	0
8	0	18	0	28	0
9	0	19	0	29	0
10	0	20	0		0

NOTE—Dry on months for which no discharge is given.

Monthly discharge of Lytle Creek at Santa Fe Railroad Bridge near Rialto, State Gage Station Index No. 10–5
For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October			0	0
November			0	0
December			0	0
January			0	0
February	.2	0		.4
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	.2	0		.4

CALWELL CREEK NEAR KEENBROOK, STATE GAGE STATION INDEX No. 13–1

LOCATION.—In SW¼, Sec. 18, T. 2 N., R. 5 W., 1 mile NE. of Keenbrook.

DRAINAGE AREA.—1.7 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on left bank of channel near road crossing.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel, steep banks, bottom gravel and small boulders. Control fair, but not permanent.

DIVERSIONS.—None.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 1.95 feet February 4, 1928 (discharge, 3.6 sec.-ft.) ; minimum discharge, dry.

ACCURACY.—Daily discharge ascertained by applying daily gage height to rating table and in interpolating for days on which the gage was not read. Record fair.

Rating table of Calwell Creek near Keenbrook, State Gage Station Index No. 13–1

Gage height	Discharge second-feet	Gage height	Discharge second-feet	Gage height	Discharge second-feet
1.50	.1	2.0	5.0	2.5	50
1.60	.2	2.1	8.8	2.7	85
1.70	.5	2.2	15.8	2.9	125
1.80	1.2	2.3	25.4	3.0	155
1.90	2.7	2.4	37.0	3.5	310

Discharge measurements of Calwell Creek near Keenbrook, State Gage Station Index No. 13–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Mar. 13	S. Carlson	1.58	.1
Feb. 16	[a]	3.9	460.0	Mar. 16	S. Carlson	1.54	.1
1928—				Mar. 19	S. Carlson	1.53	.1
Feb. 4	Lindsey	1.95	3.6	Mar. 23	S. Carlson	1.54	.1
Feb. 8	F. W. Bush	1.65	.2	Mar. 24	S. Carlson	1.58	.1
Feb. 17	S. Carlson	1 58	.1	Mar. 31	L. Berger	1 57	.1
Feb. 23	S. Carlson	1 54	.1	April 4	L. Berger	1.57	.1
Feb. 27	S. Carlson	1 55	.1	April 6	L. Berger	1 57	.1
Mar. 2	S. Carlson	1 52	.1	April 18	F. W. Bush	1.54	.1
Mar. 5	S. Carlson	1.80	1.2	April 24	F. W. Bush	0	0
Mar. 6	S. Carlson	1 71	.5	May 1	F. W. Bush	0	0
Mar. 8	S. Carlson	1 61	.2	May 17	F. W. Bush	0	0

[a] Field cross-section from high water marks by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Daily discharge in second-feet of Calwell Creek near Keenbrook, State Gage Station Index No. 13–1

For the year ending September 30, 1928

Day	Feb.	Mar.	April	Day	Feb.	Mar.	April
1	.2	.1	.1	16	.1	.1	.1
2	.2	.1	.1	17	.1	.1	.1
3	.2	.1	.1	18	.1	.1	.1
4	2.0	.1	.1	19	.1	.1	.1
5	1 0	1 8	.1	20	.1	.1	.1
6	.5	.5	.1	21	.1	.1	.1
7	.3	.3	.1	22	.1	.1	.1
8	.2	.2	.1	23	.1	.1	.1
9	.2	.2	.1	24	.1	.1	0
10	.2	.2	.1	25	.1	.1	0
11	.2	.2	.1	26	.1	.1	0
12	.2	.2	.1	27	.1	.1	0
13	.2	.2	.1	28	.1	.1	0
14	.2	.1	.1	29	.1	.1	0
15	.1	.1	.1	30		.1	0
				31		.1	

NOTE—Dry during May, June, July, August and September.

Monthly discharge of Calwell Creek near Keenbrook, State Gage Station Index No. 13–1

For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				[a]0
November				[a]4
December				[a]10
January				[a]14
February	2.0	.1	.25	14
March	1.8	.1	.19	12
April	.1	0	.08	4
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	2 0	0		58

[a] Estimated.

MEDLIN CANYON NEAR DEVORE, STATE GAGE STATION INDEX No. 14–1

LOCATION.—In the SE¼ of Sec. 20, T. 2 N., R. 5 W., 1¾ miles northwest of Devore, San Bernardino County.

DRAINAGE AREA.—0.5 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on left bank of channel.

DISCHARGE MEASUREMENTS.—None.

CHANNEL AND CONTROL.—One channel, coarse gravel and some brush. Control fair for low discharges. No rating curve obtainable.

EXTREMES OF DISCHARGE.—Unknown.

DIVERSIONS.—None.

ACCURACY.—Monthly discharge ascertained from information given by R. B. Peters.

COOPERATION.—R. B. Peters.

Monthly Discharge of Medlin Canyon near Devore,
State Gage Station Index No. 14–1
For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October			.1	6
November			.05	3
December			.1	6
January			.1	6
February			.1	6
March			.1	6
April			.05	3
May			.05	3
June			.05	3
July			.05	3
August			.05	3
September			.05	3
The year			.07	51

KIMBARK CANYON NEAR DEVORE, STATE GAGE STATION INDEX No. 15–1

LOCATION.—In the SE¼ of Sec. 21, T. 2 N., R. 5 W., 1½ miles northwest of Devore, San Bernardino County.

DRAINAGE AREA.—1.2 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage at head gate and small dam.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel; small dam forms a good permanent control.

EXTREMES OF DISCHARGE.—Maximum discharge, 2.0 second-feet on February 4, 1928; minimum discharge, 0.1 second-feet.

ACCURACY.—Gage read once a week. Daily discharge ascertained by applying gage height to rating table and by interpolation for days on which the gage was not read. Record fair.

DIVERSIONS.—None.

COOPERATION.—R. B. Peters.

Discharge measurements of Kimbark Canyon near Devore, State Gage Station Index No. 15–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				April 24	F. W. Bush	.12	2
Feb. 16	[a]	2 5	360 0	May 1	F. W. Bush	11	.2
1928—				May 17	F. W. Bush		.2
Feb. 4	H. Lindsey	20	2 0	June 4	F. W. Bush		.2
Feb. 8	F. W. Bush	.10	1 0	June 11	F. W. Bush		.2
Feb. 17	L. Berger		.5	June 20	F. W. Bush		.2
Mar. 3	S. Carlson	.05	.8	June 26	F. W. Bush		2
Mar. 13	S. Carlson		2	July 2	F. W. Bush		.2
Mar. 14	S. Carlson		.2	July 11	F. W. Bush		.2
Mar. 16	S. Carlson		.2	July 18	F. W. Bush		.2
Mar. 20	S. Carlson		2	July 25	F. W. Bush		.2
Mar. 23	S. Carlson		.2	Aug. 1	F. W. Bush		.2
Mar. 24	S. Carlson	.05	.2	Aug. 9	F. W. Bush		.2
April 4	L. Berger	.15	.4	Aug. 22	F. W. Bush		.2
April 18	F. W. Bush	.13	.3	Aug. 27	F. W. Bush		.2

[a] Field cross-section from high water marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Daily discharge of Kimbark Canyon near Devore, State Gage Station Index No. 15–1

For the year ending September 30, 1928

Day	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1	.2	1.0	.3	.1	.1	.2	.2	.2
2	.2	.9	.3	.1	.1	.2	.2	.2
3	.5	.8	.4	.1	.1	.2	.2	.2
4	2.0	.7	.5	.1	.2	.2	.2	.2
5	1.8	.6	.4	.1	.2	.2	.2	.2
6	1.5	.5	.3	.1	.2	.2	.2	.2
7	1.3	.5	.2	.1	.2	.2	.2	.2
8	1.0	.5	.2	.1	.2	.2	.2	.2
9	.9	.3	.2	.1	.2	.2	.2	.2
10	.9	.3	.2	.1	.2	.2	.2	.2
11	.8	.2	.2	.1	.2	.2	.2	.2
12	.7	.2	.2	.1	.2	.2	.2	.2
13	.7	.2	.2	.1	.2	.2	.2	.2
14	.6	.2	.2	.1	.2	.2	.2	.2
15	.5	.2	.2	.1	.2	.2	.2	.2
16	.5	.2	.2	.1	.2	.2	.2	.2
17	.5	.2	.2	.1	.2	.2	.2	.2
18	.5	.2	.2	.1	.2	.2	.2	.2
19	.6	.2	.2	.1	.2	.2	.2	.2
20	.7	.2	.2	.1	.2	.2	.2	.2
21	.8	.2	.2	.1	.2	.2	.2	.2
22	.9	2	2	1	2	.2	.2	.2
23	1.0	.2	.2	.1	.2	.2	.2	.2
24	1.0	.2	.2	.1	.2	.2	.2	.2
25	1.0	.2	.2	.1	2	2	.2	.2
26	1.0	.2	.2	.1	.2	.2	.2	.2
27	1.0	.2	.2	.1	.2	.2	.2	.2
28	1.0	.2	.2	.1	.2	.2	.2	.2
29	1.0	.2	.2	.1	.2	.2	.2	.2
30		.2	.2	.1	.2	.2	.2	.2
31		.2		.1		.2	.2	

Monthly discharge of Kimbark Canyon near Devore, State Gage Station Index No. 15–1

For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				[e]8
November				[e]12
December				[e]20
January				[e]25
February	2.0	.2	.86	49
March	1.0	.2	.33	20
April	.5	.2	.23	14
May	.1	.1	.10	6
June	.2	.1	.19	11
July	.2	.2	.2	12
August	.2	.2	.2	12
September	.2	.2	.2	12
The year	2.0	0.1		202

[e] Estimated.

EAST KIMBARK CANYON NEAR DEVORE, STATE GAGE STATION INDEX No. 16–1

LOCATION.—In SE¼ of Sec. 21, T. 2 N., R. 5 W., 1½ miles north of Devore, San Bernardino County.

DRAINAGE AREA.—0.9 square mile (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on left bank of channel.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel, steep banks, small boulders form good control, permanent for season.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 1.00 ft. on February 4, 1928 (discharge 8.1 sec.-ft.) ; minimum discharge, 0.1 sec.-ft.

DIVERSIONS.—None.

ACCURACY.—Rating curve well defined. Gage read once a week. Daily discharge ascertained by applying gage height to rating table and by interpolation on days for which the gage was not read. Record fair.

COOPERATION.—R. B. Peters, source of information for minimum flow.

Rating table of East Kimbark Canyon near Devore, State Gage Station Index No. 16–1

Gage height feet	Discharge second-feet	Gage height feet	Discharge second-feet	Gage height feet	Discharge second-feet
.0	.0	.60	.6	1.5	20
.20	.1	.70	1.3	2.0	50
.30	.2	.80	2.4	2.5	135
.40	.3	.90	4.3	3.0	182
.50	.4	1.00	8.1	3.3	230

Discharge measurements of East Kimbark Canyon near Devore, State Gage Station Index No. 16–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927				April 18	F. W. Bush	.30	.2
Feb. 16	[a]	3.30	230	April 24	F. W. Bush	.20	.2
1928—				May 1	F. W. Bush	.20	.2
Feb. 4	H. Lindsey	1.00	8.1	May 17	F. W. Bush	.16	.2
Feb. 8	F. W. Bush	.51	.4	June 4	F. W. Bush	.15	.2
Feb. 17	L. Berger	.49	.3	June 11	F. W. Bush	.15	.2
Feb. 23	S. Carlson	.45	.3	June 20	F. W. Bush		.2
Feb. 27	S. Carlson	.42	.3	June 26	F. W. Bush		.2
Mar. 2	S. Carlson	.40	.3	July 2	F. W. Bush		1
Mar. 5	S. Carlson	.42	.3	July 11	F. W. Bush		.1
Mar. 8	S. Carlson	.41	.3	July 18	F. W. Bush		.1
Mar. 13	S. Carlson	.40	.3	July 25	F. W. Bush		1
Mar. 16	S. Carlson	.40	.3	Aug. 1	F. W. Bush		.1
Mar. 20	S. Carlson	.38	.3	Aug. 9	F. W. Bush		.1
Mar. 24	S. Carlson	.38	.3	Aug. 23	F. W. Bush		.2
Mar. 31	L. Berger	.42	.3	Aug. 27	F. W. Bush		.2
April 4	L. Berger	.35	.2				

[a] Field cross-section from high water marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Monthly discharge of East Kimbark Canyon near Devore, State Gage Station Index No. 16–1

For the year ending September 30, 1928

Day	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1	.3	.3	.2	.2	.2	.1	.1	.1
2	.3	.3	.2	.2	.2	.1	.1	.1
3	.3	.3	.2	.2	.2	.1	.1	.1
4	3.0	.3	.2	.2	.2	.1	.1	.1
5	.4	.3	.2	.2	.2	.1	.1	.1
6	.4	.3	.2	.2	.2	.1	.1	.1
7	.4	.3	.2	.2	.2	.1	.1	.1
8	.4	.3	.2	.2	.2	.1	.1	.1
9	.4	.3	.2	.2	.2	.1	.1	.1
10	.4	.3	.2	.2	.2	.1	.1	.1
11	.4	.3	.2	.2	.2	.1	.1	.1
12	.4	.3	.2	.2	.2	.1	.1	.1
13	.3	.3	.2	.2	.2	.1	.1	.1
14	.3	.3	.2	.2	.2	.1	.1	.1
15	.3	.3	.2	.2	.2	.1	.1	.1
16	.3	.3	.2	.2	.2	.1	.1	.1
17	.3	.3	.2	.2	.2	.1	.1	.1
18	.3	.3	.2	.2	.2	.1	.1	.1
19	.3	.3	.2	.2	.2	.1	.1	1
20	.3	.3	.2	.2	.2	.1	.1	.1
21	.3	.3	.2	.2	.2	.1	.1	.1
22	.3	.3	.2	.2	.2	.1	.1	.1
23	.3	.3	.2	.2	.2	1	.1	1
24	.3	.3	.2	.2	.2	.1	.1	.1
25	.3	.3	.2	.2	.2	.1	.1	1
26	.3	.3	2	.2	2	1	.1	.1
27	.3	.3	.2	.2	.2	.1	.1	.1
28	.3	.3	2	.2	2	1	.1	.1
29	.3	.3	2	.2	.2	1	.1	.1
30		.3	2	.2	.2	.1	.1	.1
31		.3		.2		.1	1	

Daily discharge of East Kimbark Canyon near Devore, State Gage Station Index No. 16–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	----------	----------	----------	[e]6
November	----------	----------	----------	[e]12
December	----------	----------	----------	[e]12
January	----------	----------	----------	[e]20
February	3.0	.3	.43	25
March	.3	.3	.3	18
April	.2	.2	.2	12
May	.2	.2	.2	12
June	.2	.2	.2	12
July	.1	.1	.1	6
August	.1	.1	.1	6
September	.1	.1	.1	6
The year	3.0	.1	----------	147

[e] Estimated.

UNNAMED CANYON ONE-QUARTER MILE EAST OF EAST KIMBARK CANYON, NEAR DEVORE, STATE GAGE STATION INDEX No. 17–1

LOCATION.—In NW¼, Sec. 27, T. 2 N., R. 5W., ¼ mile east of Kimbark Canyon, 1¼ miles north of Devore, San Bernardino County.

DRAINAGE AREA.—0.2 square mile (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to July 1, 1928.

GAGE.—Staff gage on right bank of channel.

DISCHARGE MEASUREMENTS.—None.

CHANNEL AND CONTROL.—One channel coarse gravel and small boulders. Control permanent at low stages.

EXTREMES OF DISCHARGE.—Discharge of this canyon constant flow of 0.1 sec.-ft. from information furnished by R. B. Peters. No increase in discharge in normal year.

DIVERSIONS.—None.

ACCURACY.—No rating curve obtainable this season.

COOPERATION.—R. B. Peters, source of information.

Monthly discharge of Unnamed Canyon, one-quarter mile east of East Kimbark Canyon, near Devore, State Gage Station Index No. 17–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	----------	----------	.1	6
November	----------	----------	.1	6
December	----------	----------	.1	6
January	----------	----------	.1	6
February	----------	----------	.1	6
March	----------	----------	.1	6
April	----------	----------	.1	6
May	----------	----------	.1	6
June	----------	----------	.1	6
July	----------	----------	.1	6
August	----------	----------	.1	6
September	----------	----------	.1	6
The year	----------	----------	.1	72

AMES CANYON NEAR DEVORE, STATE GAGE STATION INDEX No. 18-1

LOCATION.—In center of Sec. 27, T. 2 N., R. 5 W., 1¼ miles northeast of Devore, 6½ miles north of Highland avenue, San Bernardino County.

DRAINAGE AREA.—1.0 square mile (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on right bank of channel.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel, boulders; control permanent in normal year.

EXTREMES OF DISCHARGE.—Discharge of this canyon constant flow of 0.2 sec.-ft. from information furnished by R. B. Peters.

DIVERSIONS.—None.

COOPERATION.—R. B. Peters.

Rating table of Ames Canyon near Devore,
State Gage Station Index No. 18-1

Gage height feet	Discharge second-feet	Gage height feet	Discharge second-feet
.80	.3	1.50	98
.90	4.0	1.60	128
1.00	8.0	1.70	162
1.10	17.0	1.80	199
1.20	30.0	1.90	241
1.30	48.0	2.00	284
1.40	71.0	2.10	330

Discharge measurements of Ames Canyon near Devore,
State Gage Station Index No. 18-1
For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				April 18	F. W. Bush	.74	.3
Feb. 16	[a]	2.1	330.0	May 17	F. W. Bush	.74	.2
1928—				May 30	F. W. Bush	.72	.1
April 11	F. W. Bush	.76	.2	June 20	F. W. Bush	.71	.1

[a] Field cross-sections from highwater marks, by F. W. Bush. Computed from Kutter's formula by J. A. Case.

Monthly discharge of Ames Canyon near Devore,
State Gage Station Index No. 18-1
For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October			.2	12
November			.2	12
December			.2	12
January			.2	12
February			.2	12
March			.2	12
April			.2	12
May			.2	12
June			.2	12
July			.2	12
August			.2	12
September			.2	12
The year			.2	144

CABLE CANYON WEST OF DEVIL'S CANYON, STATE GAGE STATION INDEX No. 19-1

LOCATION.—In SE¼, Sec. 26, T. 2 N., R. 5 W., 1¾ miles northeast of Devore, 2⅛ miles north of Verdemont, 6¼ miles north of Highland avenue, San Bernardino County.

DRAINAGE AREA.—2.7 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on right bank of channel.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel, coarse gravel and boulders; control can be considered permanent for season of 1927–1928.

EXTREMES OF DISCHARGE.—Maximum discharge recorded, 3.0 sec.-ft., February 4, 1928; minimum discharge, 0.1 sec.-ft.

DIVERSION.—One diversion for irrigation above station.

ACCURACY.—Gage read once a week. Daily discharge ascertained by applying gage height to rating table and by interpolation for days on which the gage was not read.

Rating table of Cable Canyon, west of Devils Canyon, State Gage Station Index No. 19–1

Gage height feet	Discharge second-feet	Gage height feet	Discharge second-feet
.60	.6	1.80	108
.80	1.1	2.00	170
1.00	5.0	2.20	244
1.20	16.0	2.30	285
1.40	34.0		
1.60	62.0		

Discharge measurements of Cable Canyon, west of Devils Canyon, State Gage Station Index No. 19–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				May 1	F. W. Bush	.69	.8
Feb. 16	[a]	2.30	285.0	May 17	F. W. Bush	.60	.6
1928—				June 4	F. W. Bush	.56	.4
Feb. 8	F. W. Bush	.80	1.1	June 11	F. W. Bush	.60	.6
Feb. 17	L. Berger	.78	.6	June 20	F. W. Bush	.61	.6
Feb. 28	S. Carlson	.75	.8	June 26	F. W. Bush	.60	.6
Mar. 3	S. Carlson	.71	.8	July 5	F. W. Bush	.52	.4
Mar. 5	S. Carlson	.73	.8	July 11	F. W. Bush	.45	.3
Mar. 8	S. Carlson	.71	.8	July 18	F. W. Bush	.40	.2
Mar. 14	S. Carlson	.72	.8	July 25	F. W. Bush	.39	.2
Mar. 23	S. Carlson	.68	.8	July 31	F. W. Bush	.38	.2
April 4	L. Berger	.80	.9	Aug. 9	F. W. Bush	.36	.1
April 6	S. Carlson	.79	.9	Aug. 23	F. W. Bush	.35	.1
April 18	F. W. Bush	.71	.8	Aug. 27	F. W. Bush	.35	.1

[a] Field cross-sections from highwater marks, by F. W. Bush. Computed from Kutter's formula by J. A. Case.

Daily discharge in second-feet of Cable Canyon, west of Devil's Canyon,
State Gage Station Index No. 19–1
For the year ending September 30, 1928

Day	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1	1.0	.5	1.0	.4	.6	.5	.2	.1
2	1.0	.5	1.0	.4	.5	.5	.2	.1
3	1.1	.5	1.0	.4	.4	.4	.2	.1
4	3.0	.5	1.0	.4	.4	.4	.1	.1
5	1.1	.6	.9	.4	.4	.4	.1	.1
6	1.1	.5	.9	.5	.4	.4	.1	.1
7	1.1	.5	.9	.5	.5	.3	.1	.1
8	1.1	.5	.9	.5	.5	.3	.1	.1
9	1.1	.5	.9	.5	.6	.3	.1	.1
10	1.0	.5	.8	.5	.6	.3	.1	.1
11	1.0	.5	.8	.6	.6	.3	.1	.1
12	.9	.5	.8	.6	.6	.3	.1	.1
13	.8	.5	.8	.6	.6	.2	.1	.1
14	.8	.5	.7	.6	.6	.2	.1	.1
15	.7	.5	.7	.6	.6	.2	.1	.1
16	.6	.5	.7	.6	.6	.2	.1	.1
17	.6	.5	.6	.6	.6	.2	.1	.1
18	.6	.5	.6	.6	.6	.2	.1	.1
19	.6	.4	.6	.6	.6	.2	.1	.1
20	.6	.4	.6	.6	.6	.2	.1	.1
21	.6	.4	.6	.6	.6	.2	.1	.1
22	.6	.4	.6	.6	.6	.2	.1	.1
23	.6	.4	.6	.6	.6	.2	.1	.1
24	.6	.4	.5	.6	.6	.2	.1	.1
25	.6	.5	.5	.6	.6	.2	.1	.1
26	.6	.6	.5	.6	.6	.2	.1	.1
27	.6	.6	.5	.6	.6	.2	.1	.1
28	.6	.7	.5	.6	.6	.2	.1	.1
29	.6	.8	.5	.6	.6	.2	.1	.1
30	--------	.9	.4	.6	.6	.2	.1	.1
31	--------	1.0	--------	.6	--------	.2	.1	--------

Monthly discharge of Cable Canyon, west of Devil's Canyon,
State Gage Station Index No. 19–1
For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	------------	------------	------------	e6
November	------------	------------	------------	e30
December	------------	------------	------------	e40
January	------------	------------	------------	e40
February	3.0	.6	.87	50
March	1.0	.4	.54	32
April	1.0	.4	.71	41
May	.6	.4	.55	34
June	.6	.4	.56	33
July	.5	.2	.26	16
August	.2	.1	.11	7
September	------------	------------	.1	6
The year	3.0	------------	------------	325

CABLE CANYON, WEST OF DEVIL'S CANYON, DIVERSION OF THE MEYER'S COMPANY PIPE LINE, STATE GAGE STATION INDEX No. 19–2

Location.—One mile upstream from state gage station on Cable Canyon.

Diversion.—The Meyer's Company diverts constantly an average of 0.6 sec.-ft. per day. A yearly discharge of 400 acre-feet is estimated.

Cooperation.—The Meyer's Company.

DEVIL'S CANYON NEAR SAN BERNARDINO, DIVERSION FOR CITY OF SAN BERNARDINO, STATE GAGE STATION INDEX No. 20–2

LOCATION.—In the SE¼ of Sec. 31, T. 2 N., R. 4 W., ½ mile upstream from U. S. G. S. gaging station, near San Bernardino, San Bernardino County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

COOPERATION.—City of San Bernardino supplies report of monthly diversion from Devil's Canyon. No daily discharge record kept.

Monthly discharge of Devil's Canyon diversion for city of San Bernardino
For the year ending September 30, 1928

Month	Run-off in acre-feet	Month	Run-off in Acre feet
October	32	May	61
November	67	June	45
December	90	July	31
January	70	August	25
February	90	September	22
March	80		
April	70	The year	683

BISHOP'S CANYON NEAR PATTON, STATE GAGE STATION INDEX No. 23–1

LOCATION.—In NW¼, Sec. 18, T. 1 N., R. 3 W., 2½ miles north of Highland avenue, east of Daley road, on line of Sterling avenue, produced north, 2¾ miles northwest of Patton, San Bernardino County.

DRAINAGE AREA.—0.7 square mile (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Painted gage on right side of culvert on private road.

DISCHARGE MEASUREMENTS.—Made by wading.

CONTROL.—Concrete box culvert makes the control.

EXTREMES OF DISCHARGE.—Maximum stage recorded 0.20 ft., February 4, 1928 (discharge 12. sec.-feet) ; minimum discharge, dry.

DIVERSION.—None.

ACCURACY.—Rating curve poorly defined. Gage height read once a week. Daily discharge ascertained by applying gage height to rating table and by interpolation for days on which the gage was not read. Record fair.

Discharge measurements of Bishop's Canyon, near Patton, State Gage Station Index No. 23–1
For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1928—				Mar. 6	S. Carlson	0	0
Feb. 4	H. Lindsey	.20	12.0	Mar. 8	S. Carlson	0	0
Feb. 11	H. Lindsey	0	0	Mar. 12	S. Carlson	0	0
Feb. 17	H. Lindsey	0	0	Mar. 15	S. Carlson	0	0
Feb. 28	S. Carlson	0	0	Mar. 19	S. Carlson	0	0
Mar. 2	S. Carlson	0	0	Mar. 23	S. Carlson	0	0
Mar. 3	Dayton Herrin	0	0	April 3	F. W. Bush	0	0

Daily discharge in second-feet of Bishop's Canyon near Patton, State Gage Station Index No. 23-1

For the year ending September 30, 1928

Day	Feb.	Mar.	Day	Feb.	Mar.	Day	Feb.	Mar.
1	0	0	11	0	0	21	0	0
2	0	0	12	0	0	22	0	0
3	0	.5	13	0	0	23	0	0
4	4.0	0	14	0	0	24	0	0
5	2.0	0	15	0	0	25	0	0
6	1.5	0	16	0	0	26	0	0
7	1.0	0	17	0	0	27	0	0
8	.5	0	18	0	0	28	0	0
9	.2	0	19	0	0	29	0	0
10	.1	0	20	0	0	30	--------	0
						31	--------	0

Note—Dry on months for which no record is given.

Monthly Discharge of Bishop's Canyon near Patton, State Gage Station Index No. 23-1

For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	------------	------------	0	0
November	------------	------------	0	0
December	------------	------------	0	0
January	------------	------------	0	0
February	4.0	0	.32	18
March	.5	0	0	1
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	4.0	0	------------	19

LITTLE SAND CANYON NEAR PATTON, STATE GAGE STATION INDEX No. 24-1

Location.—In center of Sec. 19, T. 1 N., R. 3 W., 1¾ miles north of Highland avenue, on line of Orange street, extended north, in Del Rosa District, San Bernardino County.

Drainage area.—1.2 square miles (measured on topographic map).

Records available.—October 1, 1927, to September 30, 1928.

Gage.—Staff gage on right bank of channel, ½ mile above mouth of canyon.

Discharge measurements.—Made by wading.

Channel and control.—One channel, sandy bottom; control not permanent due to scouring.

Extremes of discharge.—Maximum stage recorded, 0.30 feet, February 4, 1928 (discharge, 16.8 sec.-ft.); minimum discharge, dry.

Diversions.—None.

Accuracy.—Gage read twice a week. Daily discharge ascertained by applying daily gage height to rating table and by interpolation for days on which the gage was not read. Record fair.

Rating table of Little Sand Canyon near Patton, San Bernardino County, State Gage Station Index No. 24–1

Gage height feet	Discharge second-feet	Gage height feet	Discharge second-feet
0.10	0.1	1.5	220
0.30	16.8	2.0	525
0.50	20.0	2.5	910
0.60	25.0	3.0	1,340
0.70	35.0	3.5	1,790
0.80	45.0	4.0	2,280
0.90	60.0	4.6	2,855
1.00	80.0		

Discharge measurements of Little Sand Canyon near Patton, State Gage Station Index No. 24–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Mar. 3	Dayton Herrin	0	0
Feb. 16	[a]	4.6	2,855 0	Mar. 6	S. Carlson	0	0
1928—				Mar. 8	S. Carlson	0	0
Feb. 4	H. Lindsey	.30	16.8	Mar. 12	S. Carlson	0	0
Feb. 11	H. Lindsey	.11	.1	Mar. 15	S. Carlson	0	0
Feb. 17	H. Lindsey	0	0	Mar. 19	S. Carlson	0	0
Feb. 28	S. Carlson	0	0	Mar. 23	S. Carlson	0	0
Mar. 2	S. Carlson	0	0	April 3	F. W. Bush	0	0

[a] Field cross-sections from highwater marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Daily discharge of Little Sand Canyon near Patton, State Gage Station Index No. 24–1

For the year ending September 30, 1928

Day	February	Day	February	Day	February
1	0	11	.1	21	0
2	0	12	.1	22	0
3	0	13	.1	23	0
4	8 0	14	.1	24	0
5	5 0	15	0	25	0
6	2 0	16	0	26	0
7	1 0	17	0	27	0
8	.5	18	0	28	0
9	.3	19	0	29	0
10	.1	20	0		

Monthly discharge of Little Sand Canyon near Patton,
State Gage Station Index No. 24-1
For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	----------	----------	0	0
November	----------	----------	0	0
December	----------	----------	0	0
January	----------	----------	0	0
February	8.0	0	.6	34
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	8.0	0	----------	34

SAND CREEK NEAR PATTON, STATE GAGE STATION INDEX No. 25-1

LOCATION.—In SE¼, Sec. 19, T 1 N., R. 3 W., 1 mile northeast of Patton, at north end of Palm avenue, 1 mile north of Highland avenue, 150 feet north of Bear Valley flume, San Bernardino County.

DRAINAGE AREA.—3.1 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on right side on wing dam.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel, width is permanent; sand and gravel scouring causes shifting control.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 0.33 ft., February 4, 1928 (discharge, 65 sec.-ft.); minimum discharge, dry.

DIVERSIONS.—None.

ACCURACY.—Gage height read once a week. Rating curve fairly well defined. Daily discharge ascertained by applying daily-gage height to rating table and by interpolation for days on which the gage was not read. Record fair.

Rating Table of Sand Creek near Patton,
State Gage Station Index No. 25-1

Gage height feet	Discharge second-feet	Gage height feet	Discharge second-feet
0	0	0.70	210
0.20	0.2	0.80	260
0.30	63.0	0.90	315
0.40	85.0	1.00	375
0.50	120.0	1.50	715
0.60	160.0	2.00	1,075

Discharge measurements of Sand Creek near Patton, State Gage Station Index No. 25–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet
1927			
February 16	([a])	2.7	1.620.0
1928			
February 4	H. Lindsey	0.33	65.0
February 11	H. Lindsey	0.20	.2
February 17	H. Lindsey	0	0
February 28	S. Carlson	0	0
March 2	S. Carlson	0	0
March 3	D. Herrin	0	0
March 6	S. Carlson	0	0
March 8	S. Carlson	0	0
March 12	S. Carlson	0	0
March 15	S. Carlson	0	0
March 19	S. Carlson	0	0
March 23	S. Carlson	0	0
April 3	S. Carlson	0	0

[a] Field cross-section from highwater marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Daily discharge of Sand Creek near Patton, State Gage Station Index No. 25–1

For the year ending September 30, 1928

Day	February	Day	February	Day	February
1	0	11	.2	21	0
2	0	12	.2	22	0
3	0	13	.1	23	0
4	18.0	14	.1	24	0
5	5.0	15	.1	25	0
6	4.0	16	0	26	0
7	3.0	17	0	27	0
8	2.0	18	0	28	0
9	1.0	19	0	29	0
10	.5	20	0		

NOTE—Dry on months for which no discharge is given.

Monthly discharge of Sand Creek near Patton, State Gage Station Index No. 25–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				0
November				0
December				0
January				0
February	18	0	1.18	68
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	18	0		68

RESERVOIR CANYON NEAR HIGHLAND, STATE GAGE STATION INDEX No. 27-1

LOCATION.—In SE¼, Sec. 27, T. 1 N., R. 3 W., on Highland avenue, 2400 feet east of City Creek bridge, near Highland, San Bernardino County.

DRAINAGE AREA.—1.1 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on left bank of channel.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—Wooden box in bed of stream. Control permanent. Channel rocky with coarse gravel.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 0.30 ft., February 4, 1928 (discharge, 1.2 sec.-ft.); minimum discharge, dry.

DIVERSION.—None.

ACCURACY.—Daily discharge ascertained by using discharge measurements and by interpolation for periods between measurements. Record fair.

Rating table of Reservoir Canyon near Highland, State Gage Station Index No. 27-1

Gage height feet	Discharge second-feet	Gage height feet	Discharge second-feet
0.00	0.0	1.20	57
0.20	0.7	1.40	78
0.30	1.2	1.60	102
0.40	3.5	1.80	126
0.50	7.0	2.00	151
0.60	11.0	2.20	175
0.80	23.0	2.40	200
1.00	38.0	2.60	225

Discharge measurements of Reservoir Canyon near Highland, State Gage Station Index No. 27-1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Mar. 3	Dayton Herrin	0	0
Feb. 16	[a]	3 00	275 0	Mar. 6	S. Carlson	0	0
1928—				Mar. 8	S. Carlson	0	0
Feb. 4	H. Lindsey	0.30	1 2	Mar. 12	S. Carlson	0	0
Feb. 11	H. Lindsey	0	0	Mar. 15	S. Carlson	0	0
Feb. 17	H. Lindsey	0	0	Mar. 19	S. Carlson	0	0
Feb. 28	S. Carlson	0	0	Mar. 23	S. Carlson	0	0
Mar. 2	S. Carlson	0	0	April 3	F. W. Bush	0	0

[a] Field cross-section from high water marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Daily discharge in second-feet of Reservoir Canyon near Highland, State Gage Station Index No. 27–1

For the year ending September 30, 1928

Day	February	Day	February	Day	February
1	0	11	.1	21	0
2	0	12	0	22	0
3	0	13	0	23	0
4	1.2	14	0	24	0
5	1.0	15	0	25	0
6	.8	16	0	26	0
7	.7	17	0	27	0
8	.6	18	0	28	0
9	.3	19	0	29	0
10	.1	20	0		

NOTE.—Dry on months for which no discharge is given.

Monthly discharge of Reservoir Canyon near Highland, State Gage Station Index No. 27–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in Sec.-feet
	Maximum	Minimum	Mean	
October			0	0
November			0	0
December			0	0
January			0	0
February	1.2	0	.17	10
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	1.2	0		10

EAST HIGHLAND STORM DRAIN NEAR EAST HIGHLAND, STATE GAGE STATION INDEX No. 28–1

LOCATION.—In NE¼, Sec. 35, T. 1 N., R. 3 W., ⅝ mile north of Base Line road, ½ mile east of Church street, at crossing of government trail to Plunge Creek, near East Highland, San Bernardino County.

DRAINAGE AREA.—1.2 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on right bank of channel.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel, coarse gravel and small boulders. Control permanent for season.

EXTREMES OF DISCHARGE.—Maximum discharge recorded, 5.4 sec.-ft., February 4, 1928; minimum discharge, dry.

DIVERSIONS.—None.

ACCURACY.—Gage read once a week. Daily discharge ascertained by applying gage height to rating table and by interpolation for days on which the gage was not read. Record fair.

Discharge measurements of East Highland storm drain near East Highland, State Gage Station Index No. 28-1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				April 2	F. W. Bush	.17	.4
Feb. 16	[a]	2 3	380 0	April 18	F. W. Bush	.15	.3
1928—				May 1	F. W. Bush	.14	.3
Feb. 4	H. Lindsey	90	5 4	May 14	F. W. Bush	.10	.1
Feb. 11	H. Lindsey	41	2 5	May 28	F. W. Bush		0
Feb. 17	H. Lindsey	46	4 1	June 14	F. W. Bush		0
Feb. 28	F. W. Bush	18	4	June 27	F. W. Bush		0
Mar. 26	F. W. Bush	.14	.3				

[a] Field cross-sections from high water marks by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Daily discharge in second-feet of East Highland storm drain near East Highland, State Gage Station Index No. 28-1

For the year ending September 30, 1928

Day	Feb.	Mar.	April	May	Day	Feb.	Mar.	April	May
1	1.0	.4	.3	.3	16	2 2	.3	.3	.1
2	1 0	.4	.4	.3	17	2.1	.2	.3	.1
3	2 0	.3	.4	.3	18	2.0	.1	.3	.1
4	5 4	.4	.4	.3	19	1 8	.2	.3	.1
5	5 0	.5	.4	.3	20	1.7	.2	.3	.1
6	4.6	.6	.4	.3	21	1.5	.2	.3	.1
7	4.2	.5	.4	.3	22	1 4	.2	.3	.1
8	3 8	.4	.4	.2	23	1.2	.3	.3	.1
9	3.4	.3	.4	.2	24	1.0	.3	.3	.1
10	2 9	.2	.4	.2	25	.8	.3	.3	.1
11	2.5	.1	.4	.2	26	.7	.3	.3	.1
12	2 4	.1	.3	.1	27	.5	.3	.3	.1
13	2 4	.1	.3	.1	28	.4	.3	.3	.1
14	2.3	.3	.3	.1	29	.4	.3	.3	.1
15	2 2	.3	.3	.1	30		.3	.3	.1
					31		.3		.1

Note.—Dry during the months of June, July, August, and September.

Monthly discharge of East Highland storm drain near East Highland, State Gage Station Index No. 28-1

For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				[e]20.0
November				[e]119.0
December				[e]79.0
January				[e]50.0
February	5.4	.4	2.17	125.0
March	.6	.1	0.29	18.0
April	.4	.3	0.33	20.0
May	.3	.1	0.16	9.8
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	5.4	0		441.0

[e] Estimated.

OAK CANYON (WEST OF SANTA ANA CANYON) NEAR EAST HIGHLAND, STATE GAGE STATION INDEX No. 30–1

LOCATION.—In NE¼, Sec. 6, T. 1 S., R. 2 W., 2 miles east of East Highland, San Bernardino County, and ½ mile north of road to Santa Ana Canyon, ½ mile above canyon mouth at end of traveled road.

DRAINAGE AREA.—2.2 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on left bank of channel.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel coarse gravel, few boulders; control permanent for small discharges.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 1.80 ft., February 4, 1928 (discharge, 33.6 sec.-ft.); minimum discharge, dry.

DIVERSION.—None.

ACCURACY.—Rating curve well defined up to discharge of 34 sec.-ft. Gage height read once a week. Daily discharge ascertained by applying daily gage height to rating table and by interpolation for days on which the gage was not read. Record fair.

Rating table of Oak Canyon (west of Santa Ana Canyon) near East Highland, State Gage Station Index No. 30–1

Gage height feet	Discharge second-feet	Gage height feet	Discharge second-feet
0.0	0.0	1.10	18.2
0.10	0.1	1.20	20.4
0.20	1.5	1.30	22.5
0.30	2.8	1.40	24.8
0.40	4.5	1.50	27.1
0.50	6.0	1.60	29.3
0.60	8.0	1.70	31.5
0.70	9.8	1.80	33.6
0.80	11.7		
0.90	13.8		
1.00	16.0		

Discharge measurements of Oak Canyon (west of Santa Ana Canyon) near East Highland, State Gage Station Index No. 30–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Feb. 25	F. W. Bush	0.10	0.1
Feb. 16	[a]	5.0	1,570.0	Mar. 1	F. W. Bush	0.09	0.1
1928—				Mar. 6	F. W. Bush	0.12	0.2
Feb. 4	H. Lindsey	1.80	33.6	Mar. 9	F. W. Bush	0.10	0.1
Feb. 11	H. Lindsey	0.41	5.0	Mar. 12	F. W. Bush	0	0
Feb. 17	H. Lindsey	0.11	0.1	April 3	F. W. Bush	0	0

[a] Field cross-sections from highwater marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Daily discharge in second-feet of Oak Canyon (west of Santa Ana Canyon) near East Highland, State Gage Station Index No. 30–1

For the year ending September 30, 1928

Day	Feb.	Mar.	Day	Feb.	Mar.	Day	Feb.	Mar.
1	0.1	0.1	11	5.0	0	21	0.1	0
2	0.1	0.1	12	4.0	0	22	0.1	0
3	0.1	0.2	13	3.0	0	23	0.1	0
4	10.0	0.1	14	2.0	0	24	0.1	0
5	8.0	0.1	15	1.0	0	25	0.1	0
6	7.5	0.1	16	0.5	0	26	0.1	0
7	7.0	0.1	17	0.1	0	27	0.1	0
8	6.5	0.1	18	0.1	0	28	0.1	0
9	6.0	0.1	19	0.1	0	29	0.1	0
10	5.0	0.1	20	0.1	0	30		0
						31		0

Monthly discharge of Oak Canyon (west of Santa Ana Canyon) near East Highland, State Gage Station Index No. 30–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				0
November				[e]6
December				[e]12
January				[e]10
February	10.0	0.1	2.33	134
March	0.2	0.1	0.04	2
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	10.0	0		164

MORTON CANYON NEAR MENTONE, STATE GAGE STATION INDEX No. 32–1

Location.—In the SE¼, Sec. 9, T. 1 S., R. 2 W., 1¼ miles north and 2¼ miles east of Mentone, San Bernardino County.

Drainage area.—2.2 square miles (measured on topographic map).

Records available.—October 1, 1927, to September 30, 1928.

Gage.—Staff gage near mouth of canyon on left bank of channel.

Discharge measurements.—Made by wading.

Channel and control.—One channel, coarse gravel; control permanent for small discharges.

Diversions.—None.

Extremes of discharge.—Maximum daily discharge, 10.0 sec.-ft., February 4, 1928; minimum discharge, dry.

Accuracy.—Discharge measurements made once a week. Daily discharge ascertained by use of discharge measurements as discharge for the day and by interpolation for periods between measurements. Record fair.

Discharge measurements of Morton Canyon near Mentone.
State Gage Station Index No. 32–1
For the year ending September 30, 1928

Date	Made by	Gage height feet	Dis-charge second-feet	Date	Made by	Gage height feet	Dis-charge second-feet
1927—				April 3	F. W. Bush	0.48	0.2
Feb. 16	a	2.60	250.0	April 17	F. W. Bush	0.47	0.1
1928—				April 26	F. W. Bush	0.47	0.1
Feb. 11	H. Lindsey	0.32	6.4	May 2	F. W. Bush	0.47	0.1
Feb. 17	H. Lindsey	0.21	1.4	May 14	F. W. Bush	0.46	0.1
Feb. 24	F. W. Bush	0.20	1.3	May 22	F. W. Bush	0.45	0.1
Mar. 1	F. W. Bush	0.20	1.3	May 28	F. W. Bush	0.45	0.1
Mar. 7	F. W. Bush	0.50	0.2	June 14	F. W. Bush	0.46	0.1
Mar. 12	F. W. Bush	0.50	0.2	June 21	F. W. Bush	0.45	0.1
Mar. 16	F. W. Bush	0.50	0.2	June 27	F. W. Bush	0.45	0.1
Mar. 21	F. W. Bush	0.50	0.2	July 23	F. W. Bush	0.44	0.1
Mar. 24	F. W. Bush	0.52	0.2	Aug. 1	F. W. Bush	0.44	0.1

[a] Field cross-section from high water marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Daily discharge of Morton Canyon near Mentone,
State Gage Station Index No. 32–1
For the year ending September 30, 1928

Day	Feb.	Mar.	April	May	June	July
1	1.5	1.3	.2	.1	.1	.1
2	1.5	1.3	.2	.1	.1	.1
3	1.5	1.2	.2	.1	.1	.1
4	10.0	.8	.2	.1	.1	.1
5	6.4	.6	.2	.1	.1	.1
6	6.4	.4	.2	.1	.1	.1
7	6.4	.2	.2	.1	.1	.1
8	6.4	.2	.2	.1	.1	.1
9	6.4	.2	.2	.1	.1	.1
10	6.4	.2	.2	.1	.1	.1
11	6.4	.2	.2	.1	.1	.1
12	5.6	.2	.2	.1	.1	.1
13	4.7	.2	.2	.1	.1	.1
14	3.9	.2	.2	.1	.1	.1
15	3.0	.2	.2	.1	.1	.1
16	2.2	.2	.2	.1	.1	.1
17	1.4	.2	.2	.1	.1	.1
18	1.4	.2	.2	.1	.1	.1
19	1.4	.2	.2	.1	.1	.1
20	1.4	.2	.2	.1	.1	.1
21	1.4	.2	.2	.1	.1	.1
22	1.3	.2	.2	.1	.1	.1
23	1.3	.2	.2	.1	.1	.1
24	1.3	.2	.2	.1	.1	.1
25	1.3	.2	.2	.1	.1	.1
26	1.3	.2	.2	.1	.1	.1
27	1.3	.2	.2	.1	.1	.1
28	1.3	.2	.2	.1	.1	.1
29	1.3	.2	.2	.1	.1	.1
30		.2	.2	.1	.1	.1
31		.2		.1		.1

Monthly discharge of Morton Canyon near Mentone, State Gage Station Index No. 32–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				[a]10
November				[a]15
December				[a]20
January				[a]40
February	10.0	1.3	3.32	191
March	1.3	0.3	0.79	21
April	0.3	0.2	0.20	12
May	0.1	0.1	0.10	6
June	0.1	0.1	0.10	6
July	0.1	0.1	0.1	6
August	0.1	0	0.05	3
September	0	0	0	0
The year	10.0	0		330

SPOOR CANYON NEAR YUCAIPA GATEWAY, STATE GAGE STATION INDEX No. 34–1

Location.—In NE¼, Sec. 19, T. 1 S., R. 2 W., on Mill Creek to Yucaipa road, near Yucaipa Gateway, San Bernardino County.

Drainage area.—1.2 square miles (measured on topographic map).

Gage.—Staff gage on large wooden box culvert at road crossing of road from Mill Creek to Yucaipa.

Records available.—This canyon has several perennial springs and a constant flow of .1 of a second-foot during the rainy season, gradually reducing. A yearly discharge of 20 acre-feet is estimated for the season 1927–1928.

Discharge measurements of Spoor Canyon near Yucaipa Gateway, State Gage Station Index No. 34–1

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927— Feb. 16	[a]	3.5	880.0	1928— Mar. 24	F. W. Bush		.1

[a] Field cross-sections made from highwater marks, by F. W. Bush. Computed from Kutter's formula by J. A. Case.

WARD CANYON NEAR MENTONE, STATE GAGE STATION INDEX No. 35–1

Location.—In NW¼, Sec. 22, T. 1 S., R. 2 W., near Mill Creek road, east of Mentone, San Bernardino County.

Drainage area.—0.2 square mile (measured on topographic map).

Gage.—Staff gage on right bank of channel.

Records available.—This canyon during the season 1927–1928 had no run-off. Having a very small drainage and low altitude, only a very hard storm would cause run-off.

SAN TIMOTEO CREEK NEAR REDLANDS, STATE GAGE STATION INDEX No. 36-1

LOCATION.—In NE¼, Sec. 10, T. 2 S., R. 3 W., on Redlands-Beaumont road at bridge crossing, near Redlands, San Bernardino County.

DRAINAGE AREA.—119.6 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1926, to September 30, 1928.

GAGE.—Water-stage recorder on concrete pier right bank of channel.

DISCHARGE MEASUREMENTS.—Made by wading at low water; from bridge at high water.

CHANNEL AND CONTROL.—One channel; sandy control.

EXTREMES OF DISCHARGE.—For the year ending September 30, 1927, maximum discharge, 3000 sec.-ft., February 16, 1927; minimum discharge, dry. For the year ending September 30, 1928, maximum discharge, 59 sec.-ft., February 4, 1928; minimum discharge, dry.

ACCURACY.—Rating curve poorly defined. Control shifts due to scouring. Water stage recorder gave good record. Daily discharge ascertained by applying mean daily gage to rating table. Records good. Gage washed out February, 1927. New gage installed December, 1927, with different datum.

COOPERATION.—City of Redlands.

Discharge measurements of San Timoteo Creek near Redlands, State Gage Station Index No. 36–1

For the years ending September 30, 1927 and 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1926—				April 29	P. E. Hicks		2.9
Dec. 28	P. E. Hicks		1.0	May 3	P. E. Hicks		1.5
1927—				Dec. 27	Bush & Hicks	.24	1.7
Jan. 7	P. E. Hicks		1.4	Dec. 30	W. S. Post		3.0
Jan. 14	P. E. Hicks	3.83	.9	1928—			
Jan. 22	P. E. Hicks	3.78	1.8	Jan. 4	P. E. Hicks	.17	.2
Jan. 29	P. E. Hicks	3.99	1.0	Jan. 11	P. E. Hicks	.15	.1
Feb. 5	P. E. Hicks	3.90	1.5	Jan. 15	P. E. Hicks	.25	2.0
Feb. 12	P. E. Hicks	3.99	1.5	Jan. 16	P. E. Hicks	.16	.5
Feb. 14	P. E. Hicks	4.15	62.0	Jan. 18	P. E. Hicks	.25	1.9
Feb. 14	P. E. Hicks	4.37	197.0	Jan. 26	P. E. Hicks	.36	1.2
Feb. 14	P. E. Hicks	4.47	260.0	Feb. 2	P. E. Hicks	.40	.8
Feb. 15	P. E. Hicks	3.90	10.0	Feb. 4	P. E. Hicks	1.05	27.1
Feb. 15	P. E. Hicks		2,000.0	Feb. 4	P. E. Hicks	.97	36.8
Feb. 16	P. E. Hicks		3,000.0	Feb. 4	P. E. Hicks	1.17	46.8
Feb. 16	P. E. Hicks		2,020.0	Feb. 4	P. E. Hicks	1.33	59.4
Feb. 17	P. E. Hicks		29.0	Feb. 4	P. E. Hicks	1.45	31.6
Feb. 18	P. E. Hicks		15.3	Feb. 5	P. E. Hicks	1.15	5.2
Feb. 22	P. E. Hicks		9.4	Feb. 9	P. E. Hicks	1.05	.2
Mar. 2	P. E. Hicks		10.4	Feb. 16	P. E. Hicks	1.05	1.0
Mar. 3	P. E. Hicks		7.5	Feb. 25	P. E. Hicks	1.06	.1
Mar. 4	P. E. Hicks		46.3	Mar. 1	P. E. Hicks	.96	.2
Mar. 4	P. E. Hicks		12.6	Mar. 3	P. E. Hicks	1.16	8.9
Mar. 5	P. E. Hicks		6.2	Mar. 6	P. E. Hicks	1.28	3.2
Mar. 13	P. E. Hicks		5.3	Mar. 9	P. E. Hicks	1.18	1.9
Mar. 20	P. E. Hicks		1.8	Mar. 19	P. E. Hicks	1.07	1.1
Mar. 27	P. E. Hicks		2.3	Mar. 26	P. E. Hicks	1.18	.9
Mar. 29	P. E. Hicks		16.2	April 2	P. E. Hicks	1.06	.2
Mar. 30	P. E. Hicks		11.5	April 9	P. E. Hicks	1.05	.1
Mar. 31	P. E. Hicks		9.0	April 16	P. E. Hicks	1.06	.1
April 1	P. E. Hicks		4.9	April 25	P. E. Hicks	1.17	.1
April 3	P. E. Hicks		4.2	May 2	P. E. Hicks	.84	0
April 10	P. E. Hicks		2.9	May 9	P. E. Hicks	.88	.1
April 17	P. E. Hicks		3.4	May 16	P. E. Hicks	1.05	.2

Daily discharge in second-feet of San Timoteo Creek near Redlands, State Gage Station Index No. 36–1

For the year ending September 30, 1927

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
1	.2	.5	1.0	1.1	2.0	10.2	4.9	2.2
2	.2	.5	1.0	1.1	2.3	10.4	4.5	1.8
3	.2	.5	1.0	1.2	2.6	7.5	4.2	1.5
4	.2	.5	1.0	1.2	3.0	6.8	4.0	0
5	.2	.5	1.0	1.3	1.5	6.2	3.9	0
6	.2	.5	1.0	1.3	1.5	6.0	3.7	0
7	.2	.5	1.0	1.4	1.5	5.9	3.5	0
8	.2	.5	1.0	1.3	1.5	5.8	3.3	0
9	.2	.5	1.0	1.3	1.5	5.7	3.1	0
10	.2	.5	1.0	1.2	1.5	5.6	2.9	0
11	.2	.5	1.0	1.1	1.5	5.5	2.9	0
12	.2	.5	1.0	1.1	1.5	5.4	3.0	0
13	.2	.5	1.0	1.0	9.0	5.3	3.0	0
14	.2	.5	1.0	.9	150.0	4.8	3.1	0
15	.2	.5	1.0	1.0	1,150.0	4.3	3.2	0
16	.3	.5	1.2	1.2	1,840.0	3.8	3.3	0
17	.3	.5	1.3	1.3	150.0	3.2	3.4	0
18	.3	.5	1.4	1.4	15.0	2.8	3.4	0
19	.3	.5	2.0	1.5	14.0	2.3	3.4	0
20	.3	.5	2.5	1.6	12.0	1.8	3.3	0
21	.3	.5	3.0	1.7	11.0	1.8	3.3	0
22	.3	.5	2.5	1.8	9.4	1.9	3.2	0
23	.3	.5	2.5	1.7	9.4	1.9	3.2	0
24	.3	.5	1.1	1.6	9.5	2.0	3.2	0
25	.3	.5	1.1	1.4	9.6	2.1	3.1	0
26	.3	.5	1.1	1.3	9.7	2.2	3.1	0
27	.3	.5	1.1	1.2	9.8	2.3	3.1	0
28	.3	.5	1.1	1.1	9.9	9.2	3.1	0
29	.3	.5	1.1	1.0	....	16.2	2.9	0
30	.3	.5	1.1	1.3	....	11.5	2.5	0
31	.3	.....	1.1	1.6	....	9.0	....	0

Daily discharge in second-feet of San Timoteo Creek near Redlands, State Gage Station Index No. 36–1

For the year ending September 30, 1928

Day	Dec.	Jan.	Feb.	Mar.	April	May
1	.2	.6	.8	.2	.2	0
2	.2	.4	.8	.2	.2	0
3	.2	.3	1.0	6.0	.2	.1
4	.2	.2	21.8	5.0	.2	.1
5	.2	.2	5.2	3.0	.2	.1
6	.2	.2	4.0	3.0	.1	.1
7	.2	.3	2.8	2.5	.1	.1
8	.2	.3	1.0	1.9	.1	.1
9	.2	.2	.2	1.9	.1	.1
10	.2	.2	2.5	1.9	.1	.2
11	.3	.2	3.0	1.8	.1	.2
12	.3	.2	2.5	1.8	.1	.2
13	.3	.2	2.5	1.7	.1	.2
14	.3	.2	2.5	1.7	.1	.2
15	.3	.4	1.0	1.7	.1	.2
16	.3	.3	1.0	1.5	.1	.2
17	.3	.8	.9	1.4	.1	.1
18	.3	2.0	.8	1.3	.1	.1
19	.3	1.8	.7	1.1	.1	.1
20	.3	1.8	.6	1.1	.1	0
21	.3	1.6	.6	1.1	.1	0
22	.3	1.6	.5	1.0	.1	0
23	.3	1.3	.3	1.0	.1	0
24	.3	1.3	.2	1.0	.1	0
25	.3	1.2	.1	.9	.1	0
26	.3	1.2	.1	.9	.1	0
27	1.3	1.2	.1	.8	.1	0
28	1.3	1.0	.1	.7	.1	0
29	2.0	.8	.1	.6	.1	0
30	3.0	.8	....	.4	.1	0
31	.8	.8	....	.3	....	0

NOTE—Dry on months for which no discharge is given, except probably small flow in November, 1927.

Monthly discharge of San Timoteo Creek near Redlands, State Gage Station Index No. 36–1

For the year ending September 30, 1927

Month, 1926-1927	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	.3	.2	.25	15
November	.5	.5	.5	31
December	3.0	1.0	1.30	80
January	1.8	.9	1.30	80
February	1,840.0	1.5	123.0	7,560
March	16.2	1.8	5.46	336
April	4.9	2.5	3.35	206
May	2.2	0	.18	11
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	1,840.0	0	11.3	8,320

Monthly discharge of San Timoteo Creek near Redlands, State Gage Station Index No. 36–1

For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				0
November				[e]15.0
December	3.0	.2	.49	30.1
January	2.0	.2	.76	46.7
February	21.8	.1	1.99	114.0
March	6.0	.2	1.59	97.7
April	.2	.1	.12	7.1
May	.2	0	.08	4.9
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	21.8	0	.44	316.0

[e] Estimated.

RECHE CANYON NEAR REDLANDS, STATE GAGE STATION INDEX No. 38–1

LOCATION.—In SW¼, Sec. 27, T. 1 S., R. 4 W., 3½ miles east of Bryn Mar on the Redlands-Riverside road near Gage Canal crossing, near Redlands, San Bernardino County.

DRAINAGE AREA.—11.6 square miles (measured on topographic map).

GAGE.—Staff gage on south side of bridge near Gage Canal crossing.

RECORDS AVAILABLE.—This canyon is dry except in very heavy rains; during the season 1927–1928 the discharge was estimated as 5 acre-feet.

Discharge measurements of Reche Canyon near Redlands, State Gage Station Index No. 38–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1928— Feb. 11	H. Lindsey	0	0	Feb. 17	H. Lindsey	0	0

SANTA ANA RIVER AT COLTON, STATE GAGE STATION INDEX No. A-1

LOCATION.—At Mt. Vernon Highway bridge, 600 ft. south of Southern Pacific R. R., one block east of Southern Pacific shops, 300 ft. east of Riverside Water Company's canal, at Colton, San Bernardino County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Water-stage recorder on west buttress of bridge.

DISCHARGE MEASUREMENTS.—Made by wading at low water; from bridge at high water.

CHANNEL AND CONTROL.—Stream splits into several channels at normal discharge, low discharge one channel. Sandy bottom control shifts.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 3.78 ft., February 4, 1928 (discharge, 1000 sec.-ft.); minimum discharge, dry.

DIVERSIONS.—Numerous diversions for irrigation above station.

ACCURACY.—Daily discharge ascertained by applying mean gage heights to rating table. Water-stage recorder gave good record from time of installation, December 16, 1927. Rating curve fairly well defined. Record good.

Discharge measurements of Santa Ana River at Colton, State Gage Station Index No. A-1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Mar. 16	F. W. Bush	2.80	13.5
Feb. 16	[a]	6.00	6,202.0	Mar. 23	F. W. Bush	2.67	3.4
Dec. 16	F. W. Bush	2.81	19.8	April 6	F. W. Bush	2.59	2.8
Dec. 27	F. W. Bush	3.04	31.0	April 13	F. W. Bush	2.52	2.1
1928—				April 20	F. W. Bush	2.46	2.4
Jan. 3	F. W. Bush	2.93	19.7	May 3	F. W. Bush	2.41	1.8
Jan. 10	F. W. Bush	3.02	33.1	May 9	J. A. Case	2.43	2.1
Jan. 17	F. W. Bush	3.00	22.1	May 14	F. W. Bush	2.47	1.7
Jan. 24	F. W. Bush	3.21	95.0	May 22	F. W. Bush	2.54	1.9
Jan. 31	F. W. Bush	2.79	29.1	May 29	F. W. Bush	2.46	1.6
Feb. 4	F. W. Bush	3.38	310.0	June 5	F. W. Bush		1.6
Feb. 4	F. W. Bush	3.69	853.0	June 12	F. W. Bush		1.3
Feb. 4	F. W. Bush	3.63	720.0	June 19	F. W. Bush		1.7
Feb. 5	F. W. Bush	3.20	190.0	June 29	F. W. Bush		.6
Feb. 5	F. W. Bush	3.10	131.0	July 2	F. W. Bush		.6
Feb. 10	F. W. Bush	2.70	25.6	July 12	F. W. Bush		.5
Feb. 24	F. W. Bush	2.77	20.8	July 19	F. W. Bush		.4
Mar. 2	F. W. Bush	2.72	14.2	July 26	F. W. Bush		.4
Mar. 3	F. W. Bush	2.81	29.0	Aug. 1	F. W. Bush		.4
Mar. 9	F. W. Bush	2.85	25.1	Aug. 7	F. W. Bush		.2
Mar. 14	F. W. Bush	2.86	28.5	Aug. 21	F. W. Bush		0

[a] Field cross-sections from high water marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

*Daily discharge in second-feet of Santa Ana River at Colton,
State Gage Station Index No. A–1*

For the year ending September 30, 1928

Day	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.
1		25	17	12.0	3.3	1.8	1.6	.6	.4
2		24	14	20.0	3.3	1.8	1.6	.6	.4
3		23	17	21.0	3.9	1.8	1.6	.6	.3
4		24	385	22.0	3.0	1.8	1.6	.6	.3
5		25	137	27.0	2.9	1.7	1.5	.6	.3
6		25	25	38.0	2.8	1.7	1.5	.6	.2
7		25	17	23.0	2.7	1.7	1.5	.5	.2
8		26	18	22.0	2.6	1.7	1 5	5	.2
9		28	17	25.0	2.6	2.1	1.4	.5	.2
10		31	26	25.0	2.6	23.0	1.4	.5	.1
11		29	20	25.0	2.6	3.0	1.4	.5	.1
12		30	17	27.0	2.6	1.9	1.3	.5	.1
13		31	18	32.0	2.6	1.9	1.4	.5	.1
14		30	18	32.0	2.6	2.3	1.4	.5	.1
15		33	18	25.0	2.3	2.3	1.5	.4	.1
16	20	38	16	13.0	2.3	2.1	1.5	.4	.1
17	20	28	18	4.2	2.3	2.1	1.6	.4	0
18	20	29	18	3.9	2.2	2.0	1.6	.4	0
19	20	28	18	4.1	2.1	2.0	1.7	.4	0
20	22	28	18	4.0	2.4	1.9	1.7	.4	0
21	51	42	18	3.6	2.0	1.9	1.6	.4	0
22	31	35	18	3.5	2.0	1.9	1 3	4	0
23	24	31	18	3.3	1.9	1.8	1.3	.4	0
24	23	46	12	3.5	1.9	1.8	1.3	.4	0
25	24	54	21	3.5	1.9	1.8	1.2	.4	0
26	38	42	20	3.3	1.8	1.7	1.2	.4	0
27	32	39	21	3 0	1.8	1.7	1.0	.4	0
28	27	23	18	3.1	1.9	1.6	.9	.4	0
29	30	19	12	3.3	1.9	1.6	.7	.4	0
30	65	19		3 3	1.9	1.6	.6	.4	0
31	27	18		3.3		1.6		.4	0

*Monthly discharge of Santa Ana River at Colton,
State Gage Station Index No. A–1*

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				0
November				[e]870
December	51.0	20.0	26.1	1,605
January	54.0	18 0	29.9	1,838
February	385.0	12.0	34.8	2,002
March	38.0	3.0	14.2	817
April	3.9	1.9	2.42	144
May	23.0	1.6	2.57	158
June	1.7	.6	1.35	80
July	.6	.4	.46	28
August	.4	0	.10	6
September	0	0	0	0
The year	385.0	0	10.4	7,550

BOX SPRINGS CANYON NEAR RIVERSIDE, STATE GAGE STATION INDEX No. 39-1

LOCATION.—In SW¼, Sec. 29, T. 2 S., R. 4 W., at crossing of Canyon Crest road, ¼ mile south of Riverside-Perris highway, near Riverside, Riverside County.

DRAINAGE AREA.—3.6 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage near crossing of Canyon Crest road.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel, no well-defined control, sandy bottom; control not permanent.

EXTREMES OF DISCHARGE.—Maximum discharge, 1.0 sec.-ft., February 4, 1928; minimum discharge, dry.

ACCURACY.—Daily discharge record estimated.

Discharge measurements of Box Springs Canyon near Riverside, State Gage Station Index No. 39-1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Mar. 7	S. Carlson	0	0
Feb. 16	[a]	1.70	65.0	Mar. 12	S. Carlson	0	0
1928—				Mar. 15	S. Carlson	0	0
Feb. 25	W. S. Post	0	0	Mar. 19	S. Carlson	0	0
Mar. 1	S. Carlson	0	0	Mar. 23	S. Carlson	0	0
Mar. 3	L. Alexander	0	0	April 5	F. W. Bush	0	0

[a] Field cross-section from highwater marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Daily discharge in second-feet of Box Springs Canyon near Riverside, State Gage Station Index No. 39-1

For the year ending September 30, 1928

Day	February	Day	February	Day	February
1	0	11	0	21	0
2	0	12	0	22	0
3	0	13	0	23	0
4	1.0	14	0	24	0
5	.5	15	0	25	0
6	.3	16	0	26	0
7	.2	17	0	27	0
8	.1	18	0	28	0
9	0	19	0	29	0
10	0	20	0		

NOTE—Dry on months for which no discharge is given.

Monthly discharge of Box Springs Canyon near Riverside, State Gage Station Index No. 39–1
For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	----------	----------	----------	0
November	----------	----------	----------	0
December	----------	----------	----------	0
January	----------	----------	----------	0
February	1.0	0	.07	4
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	1.0	0	----------	4

SYCAMORE CANYON NEAR RIVERSIDE, STATE GAGE STATION INDEX No. 40–1

LOCATION.—In the SW¼, Sec. 32, T. 2 S., R. 4 W., 2½ miles southeast of Riverside, near Canyon Crest road, in Riverside County.

DRAINAGE AREA.—9.5 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage near Canyon Crest road crossing, on left bank of channel.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel, no well-defined control, sandy bottom.

EXTREMES OF DISCHARGE.—Maximum discharge, 2.0 sec.-ft., February 4, 1928; minimum discharge, dry.

ACCURACY.—Discharge record estimated.

Discharge measurements of Sycamore Canyon near Riverside, State Gage Station Index No. 40–1
For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Mar. 7	S. Carlson	0	0
Feb. 16	[a]	1.20	525.0	Mar. 12	S. Carlson	0	0
1928—				Mar. 15	S. Carlson	0	0
Feb. 4	W. S. Post	----------	2.0	Mar. 19	S. Carlson	0	0
Feb. 24	W. S. Post	0	0	Mar. 23	S. Carlson	0	0
Mar. 1	S. Carlson	0	0	April 5	F. W. Bush	0	0

[a] Field cross-sections from highwater marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case

Daily discharge in second-feet of Sycamore Canyon near Riverside, State Gage Station Index No. 40–1
For the year ending September 30, 1928

Day	February	Day	February	Day	February
1	0	11	0	21	0
2	0	12	0	22	0
3	0	13	0	23	0
4	.5	14	0	24	0
5	.3	15	0	25	0
6	.2	16	0	26	0
7	.1	17	0	27	0
8	0	18	0	28	0
9	0	19	0	29	0
10	0	20	0		

NOTE—Dry during months for which no discharge is given.

Monthly discharge of Sycamore Canyon near Riverside, State Gage Station Index No. 40–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				0
November				[e]2
December				0
January				0
February	.5	0	.04	2
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	.5	0		4

UNNAMED CREEK NEAR RIVERSIDE, STATE GAGE STATION INDEX No. 41–1

LOCATION.—In SW¼ of Sec. 15, T. 3 S., R. 5 W., at intersection of roads, 2 miles southeast of Casa Blanca, 1½ miles east of Mockingbird Canyon, near Riverside, Riverside County.

DRAINAGE AREA.—7.3 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage at lower end of concrete box culvert.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel; concrete culvert forms permanent control.

EXTREMES OF DISCHARGE.—Maximum discharge, 1.5 sec.-ft., February 4, 1928; minimum discharge, dry.

ACCURACY.—Discharge record estimated.

Discharge measurements of unnamed creek near Riverside, State Gage Station Index No. 41–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Mar. 3	S. Carlson	0	0
Feb. 16	[a]	2 4	225 0	Mar. 15	S. Carlson	0	0
1928—				Mar. 19	S. Carlson	0	0
Feb. 25	S. Carlson	0	0	Mar. 23	S. Carlson	.0	0
Mar. 1	S. Carlson	0	0	April 5	F. W. Bush	0	0

[a] Field cross-sections from highwater marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case

Daily discharge in second-feet of unnamed creek near Riverside, State Gage Station Index No. 41–1

For the year ending September 30, 1928

Day	February	Day	February	Day	February
1	0	11	.1	21	0
2	0	12	.1	22	0
3	0	13	0	23	0
4	.5	14	0	24	0
5	.5	15	0	25	0
6	.3	16	0	26	0
7	.2	17	0	27	0
8	.1	18	0	28	0
9	.1	19	0	29	0
10	.1	20	0		

Monthly discharge of unnamed creek near Riverside, State Gage Station Index No. 41–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				0
November				[e]4
December				0
January				0
February	.5	0	.07	4
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	.5	0		8

[e] Estimated.

MOCKINGBIRD CANYON NEAR ARLINGTON, STATE GAGE STATION INDEX No. 42–1

LOCATION.—In the SW¼ of Sec. 27, T. 3 S., R. 5 W., one mile upstream from Mockingbird Reservoir, near Arlington, Riverside County.

DRAINAGE AREA.—10.5 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on left bank of channel, near edge of road crossing.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—One channel, sandy bottom; no permanent control.

EXTREMES OF DISCHARGE.—Maximum discharge, 10 sec.-ft., February 4, 1928; minimum discharge, dry.

ACCURACY.—Discharge record estimated.

Discharge measurements of Mockingbird Canyon near Arlington, State Gage Station Index No. 42–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Mar. 7	S. Carlson	0	0
Feb. 16	[a]	2 60	330 0	Mar. 12	S. Carlson	0	0
1928—				Mar. 15	S. Carlson	0	0
Feb. 4	W. S. Post		[c]10 0	Mar. 19	S. Carlson	0	0
Mar. 1	S. Carlson	0	0	Mar. 23	S. Carlson	0	0
Mar. 3	L. Alexander	0	0	April 5	F. W. Bush	0	0

[a] Field cross-section from highwater marks, by F. W. Bush. Computed from Kutter's formula by J. A. Case.
[c] Estimated.

Daily discharge in second-feet of Mockingbird Canyon near Arlington, State Gage Station Index No. 42–1

For the year ending September 30, 1928

Day	February	Day	February	Day	February
1	0	11	0	21	0
2	0	12	0	22	0
3	0	13	0	23	0
4	4 0	14	0	24	0
5	2 0	15	0	25	0
6	1 0	16	0	26	0
7	.5	17	0	27	0
8	.1	18	0	28	0
9	0	19	0	29	0
10	0	20	0		

Monthly discharge of Mockingbird Canyon near Arlington, State Gage Station Index No. 42–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October				0
November				[e]10
December				[e]7
January				0
February	4.0	0	.26	15
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
The year	4.0	0		32

[e] Estimated.

SANTA ANA RIVER AT PEDLEY BRIDGE NEAR ARLINGTON, STATE GAGE STATION INDEX No. B–1

LOCATION.—In SW¼, Sec. 25, T. 2 S., R. 6 W., at highway bridge, one mile southeast of Pedley, three miles north of Arlington on North Van Buren street, Riverside County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Water-stage recorder on first pier from west end of bridge.

DISCHARGE MEASUREMENTS.—Made by wading at low water; from bridge at high water.

CHANNEL AND CONTROL.—Channel is split into several small channels, bottom sandy and scours; control is not permanent.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 1.70 ft., February 4, 1928 (discharge, 1250 sec.-ft.); minimum daily discharge, 28 sec.-ft., August 24, 1928.

DIVERSION.—Numerous diversions for irrigation above station.

ACCURACY.—Rating curve poorly defined. Water-stage recorder gave good record. Daily discharge ascertained by applying mean daily gage height to rating table. Record good.

Discharge measurements of Santa Ana River at Pedley Bridge near Arlington, State Gage Station Index No. B–1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				April 21	F. W. Bush	.87	45
Feb. 16	[a]	5.2	15,400	April 30	F. W. Bush	.83	37
Dec. 1	H. C. Troxell		102	May 12	F. W. Bush	.99	82
Dec. 16	H. C. Troxell		118	May 26	F. W. Bush	.84	45
Dec. 27	F. W. Bush		90	June 2	F. W. Bush	.82	56
1928—				June 9	F. W. Bush	.82	40
Jan. 4	H. C. Troxell	1.03	103	June 11	[b]J. Oliver	.82	36
Jan. 9	H. C. Troxell	1.01	104	June 16	F. W. Bush	.81	40
Jan. 17	H. C. Troxell	1.06	119	June 23	F. W. Bush	.80	43
Jan. 19	H. C. Troxell	1.03	108	June 25	J. Oliver	.83	40
Jan. 26	H. C. Troxell	1.00	106	June 30	F. W. Bush	.80	40
Feb. 2	H. C. Troxell	1.02	97	July 2	J. Oliver	.83	29
Feb. 4	L. Alexander	1.22	301	July 7	F. W. Bush	.78	39
Feb. 4	L. Alexander	1.34	340	July 14	F. W. Bush	.76	40
Feb. 4	L. Alexander	1.31	854	July 16	J. Oliver		29
Feb. 4	L. Alexander	1.45	1,022	July 21	F. W. Bush	.80	37
Feb. 8	H. C. Troxell	1.15	137	July 26	J. Oliver		28
Feb. 15	H. C. Troxell	1.11	137	Aug. 3	J. Oliver		29
Feb. 23	H. C. Troxell	1.10	121	Aug. 4	F. W. Bush	.78	46
Feb. 29	H. C. Troxell	1.00	99	Aug. 10	J. Oliver		34
Mar. 3	L. Alexander	1.14	159	Aug. 15	F. W. Bush	.76	35
Mar. 3	L. Alexander	1.10	125	Aug. 17	J. Oliver		33
Mar. 5	L. Alexander	1.10	132	Aug. 24	[b]F. W. Bush	.76	27
Mar. 9	H. C. Troxell	1.12	127	Aug. 24	[b]F. C. Ebert		28
Mar. 14	H. C. Troxell	1.12	136	Aug. 30	F. W. Bush	.76	34
Mar. 21	H. C. Troxell	.95	69	Sept. 4	J. Oliver		32
Mar. 28	H. C. Troxell	.95	56	Sept. 13	J. Oliver		31
April 14	F. W. Bush	.86	40	Sept. 26	J. Oliver		36

[a]Field cross-section from highwater marks, by F. W. Bush. Computed from Kutter's formula, by J. A. Case.
[b]Engineer, U. S. Geological Survey.

Daily discharge in second-feet of Santa Ana River at Pedley Bridge near Arlington, State Gage Station Index No. B-1

For the year ending September 30, 1928

Day	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1	102	98	106	102	50	39	55	37	36	33
2	103	99	103	102	43	40	56	37	35	33
3	104	101	109	108	58	40	53	38	35	32
4	105	103	533	110	60	41	50	38	35	32
5	106	103	200	108	54	41	48	38	35	32
6	107	103	135	159	52	40	45	39	35	32
7	108	104	135	128	46	40	43	39	35	31
8	109	104	142	136	46	40	40	39	34	31
9	110	104	127	125	45	60	40	39	34	31
10	111	106	118	128	44	75	40	40	34	31
11	112	107	120	128	42	85	40	40	35	31
12	113	109	120	128	41	75	40	40	35	31
13	114	110	120	138	40	48	40	40	35	31
14	115	112	120	124	40	50	40	40	35	31
15	116	114	120	120	41	54	40	39	35	30
16	118	117	108	120	42	52	40	39	34	30
17	115	119	108	121	42	50	40	38	33	30
18	113	108	114	108	42	48	40	38	33	30
19	110	108	112	105	44	48	41	37	32	30
20	108	110	118	98	44	46	43	37	31	31
21	105	120	110	70	45	46	43	36	30	31
22	103	110	108	63	45	46	43	36	30	32
23	100	118	110	60	43	45	43	36	29	33
24	97	112	110	48	42	45	43	36	28	34
25	94	108	106	60	42	45	41	36	30	35
26	92	108	104	60	40	45	40	36	30	36
27	90	102	104	60	43	47	40	36	31	36
28	91	102	100	63	42	48	39	36	32	36
29	93	102	102	54	40	50	38	36	32	37
30	94	102	--------	58	37	52	37	36	33	37
31	96	106	--------	58	--------	54	--------	36	33	--------

Monthly discharge of Santa Ana River at Pedley Bridge near Arlington, State Gage Station Index No. B-1

For the year ending September 30, 1928

Month, 1927-1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	------------	------------	------------	[e]2,000
November	------------	------------	------------	[e]4,200
December	118	90	105.0	6,460
January	119	98	107.0	6,600
February	533	102	132.0	7,590
March	159	58	98.4	6,050
April	60	37	44.5	2,650
May	85	39	49.4	3,040
June	55	37	42.7	2,540
July	40	36	37.7	2,320
August	36	28	33.1	2,040
September	37	30	32.3	1,920
The year	533	28	------------	47,400

[e] Estimated.

CHINO CREEK NEAR CHINO, STATE GAGE STATION INDEX No. C-2

LOCATION.—In the SW¼ of Sec. 20, T. 3 S., R. 7 W., at bridge crossing on the Chino road to Rincon, near Chino.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Water-stage recorder on west wing wall of bridge.

DISCHARGE MEASUREMENTS.—Made by wading at low water; from bridge at high water.

CHANNEL AND CONTROL.—One channel; no well-defined control.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 3.40 ft., March 6, 1928 (discharge, 52 sec.-ft.); minimum discharge, 0.7 sec.-ft., June 26, 27, 30 and July 1.

ACCURACY.—Rating curve well defined. Water stage recorder gave good record. Daily discharge ascertained by applying mean daily gage height to rating table, or by interpolation between measurements for periods when the recorder was not in operation. Record good.

Rating table of Chino Creek near Chino, State Gage Station Index No. C-2

Gage height feet	Discharge second-feet	Gage height feet	Discharge second-feet
.95	1.7	2.60	24
1.16	2.9	2.80	30
1.50	4.8	3.00	37
1.75	9.0	3.10	41
1.90	11.2	3.20	45
2.00	13.5	3.30	48
2.20	16.0	3.40	52
2.40	19.0	3.50	56

Discharge measurements of Chino Creek near Chino, State Gage Station Index No. C-2

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Mar. 14	H. C. Troxell	2.30	18.0
Feb. 16	[a]		1270.0	Mar. 21	H. C. Troxell	2.00	13.6
Dec. 1	H. C. Troxell		11.0	Mar. 29	H. C. Troxell	1.88	11.0
Dec. 16	H. C. Troxell		12.0	April 5	L. Berger	1.74	9.1
Dec. 21	Shiffer	2.35	13.0	April 19	F. W. Bush	1.37	4.1
1928—				April 25	F. W. Bush	.95	1.7
Jan. 4	H. C. Troxell	2.38	16.0	May 3	F. W. Bush	1.16	2.9
Jan. 9	H. C. Troxell	2.24	14.0	May 16	F. W. Bush	1.49	4.6
Jan. 19	H. C. Troxell	2.30	18.0	June 5	F. W. Bush	1.34	3.4
Jan. 25	H. C. Troxell	2.25	17.0	June 12	F. W. Bush	.98	1.8
Feb. 2	H. C. Troxell	2.22	16.0	June 19	F. W. Bush	1.13	1.7
Feb. 8	H. C. Troxell	2.60	24.0	June 26	F. W. Bush	.92	.7
Feb. 16	H. C. Troxell	2.30	18.0	July 3	F. W. Bush	.97	.9
Feb. 29	H. C. Troxell	2.12	15.0	July 19	F. W. Bush	1.17	1.8
Mar. 5	F. W. Bush	2.82	30.0	July 26	F. W. Bush	1.31	2.8
Mar. 6	F. W. Bush	3.05	39.0	Aug. 2	F. W. Bush	1.18	1.7
Mar. 6	F. W. Bush	3.40	52.0	Aug. 16	F. W. Bush	1.20	1.8
Mar. 6	H. C. Troxell	3.35	51.0	Aug. 24	F. W. Bush	1.18	1.7
Mar. 9	H. C. Troxell	2.32	19.0				

[a] Field cross-sections from highwater marks, by F. W. Bush, Jr. Computed from Kutter's formula, by J. A. Case.

Daily discharge in second-feet of Chino Creek near Chino, State Gage Station Index No. C–2

For the year ending September 30, 1928

Day	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1	11.0	14.8	16.3	15.6	11.2	2.6	3.6	.7	1.9	1.8
2	11.1	14.9	16.2	15.7	10.6	2.8	3.6	.8	1.7	1.8
3	11.2	15.0	17.4	16.3	10.6	2.9	3.5	.9	1.7	1.8
4	11.3	15.2	50.0	19.0	10.2	3.0	3.5	1.0	1.7	1.8
5	11.4	15.3	45.0	21.1	9.7	3.2	3.4	1.0	1.7	2.0
6	11.5	15.5	30.0	45.0	8.9	3.3	3.4	1.1	1.7	2.0
7	11.6	15.6	25.0	41.8	8.9	3.4	3.0	1.1	1.7	2.0
8	11.7	15.7	23.6	16.8	8.8	3.6	3.0	1.2	1.8	2.0
9	11.8	15.9	22.8	17.8	8.7	3.7	2.8	1.3	1.8	2.0
10	11.9	16.0	22.1	17.4	8.7	3.8	2.5	1.3	1.8	2.2
11	12.0	16.2	21.3	17.4	8.6	3.9	2.0	1.4	1.8	2.2
12	12.1	16.3	20.5	17.8	8.5	4.1	1.8	1.4	1.8	2.2
13	12.2	16.4	19.7	17.8	8.4	4.2	1.8	1.5	1.8	2.4
14	12.3	16.6	19.0	17.8	7.7	4.3	1.8	1.6	1.8	2.4
15	12.4	16.9	18.2	17.0	7.0	4.5	1.7	1.6	1.8	2.4
16	12.5	17.2	17.4	17.0	6.3	4.6	1.8	1.7	1.8	2.6
17	12.6	17.4	17.3	17.0	5.6	4.5	1.8	1.7	1.8	2.6
18	12.8	17.7	17.4	15.6	4.9	4.5	1.7	1.8	1.7	2.8
19	12.9	18.0	17.4	15.7	4.1	4.4	1.7	1.8	1.7	2.8
20	13.1	18.0	17.4	15.0	3.7	4.4	1.7	1.9	1.7	2.8
21	13.2	17.9	17.6	13.8	3.3	4.3	1.7	2.1	1.7	2.8
22	13.3	17.7	17.4	12.4	2.9	4.2	1.5	2.2	1.7	3.0
23	13.5	17.6	17.0	12.4	2.5	4.2	1.3	2.4	1.7	3.0
24	13.6	17.5	16.3	12.4	2.1	4.1	1.1	2.5	1.7	3.0
25	13.8	17.2	16.3	12.4	1.7	4.1	.9	2.6	1.7	3.0
26	13.9	17.1	16.3	12.4	1.8	4.0	.7	2.8	1.7	3.2
27	14.1	17.0	16.3	12.4	2.0	3.9	.7	2.6	1.7	3.2
28	14.2	16.8	16.3	12.4	2.2	3.9	.8	2.4	1.7	3.4
29	14.3	16.7	15.3	12.4	2.3	3.8	.8	2.2	1.7	3.4
30	14.5	16.6	--------	11.3	2.4	3.8	.7	2.1	1.7	3.6
31	14.6	16.5	--------	11.3	--------	3.7	--------	2.0	1.7	--------

Monthly discharge of Chino Creek near Chino, State Gage Station Index No. C–2

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	------------	------------	------------	[e]200
November	------------	------------	------------	[e]800
December	14.6	11.0	12.66	778
January	18.0	14.8	16.55	1,018
February	50.0	15.3	20.78	1,195
March	45.0	11.3	17.10	1,051
April	11.2	1.7	6.14	365
May	4.6	2.6	3.86	237
June	3.6	.7	2.01	120
July	2.8	.7	1.70	104
August	1.9	1.7	1.74	107
September	3.6	1.8	2.54	151
The year	50.0	.7	8.45	6,130

[e] Estimated.

TEMESCAL CREEK NEAR CORONA, STATE GAGE STATION INDEX No. 44-1

LOCATION.—In SW¼ of Sec. 1, T. 4 S., R. 6 W., 3½ miles southeast of Corona, 1 mile north of road from Corona to Elsinore, near Corona, Riverside County.

DRAINAGE AREA.—115.8 square miles (measured on topographic map), does not include Lake Elsinore.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage on right bank of channel.

CHANNEL AND CONTROL.—One channel; no well-defined control, bottom sandy.

EXTREMES OF DISCHARGE.—Maximum discharge, 2.7 sec.-ft., February 13–15, 1928; minimum discharge, 0.6 sec.-ft.

ACCURACY.—Daily discharge ascertained by using measurements as daily discharge and by interpolation between measurements for days on which no measurements were made. Record fair.

Discharge measurements of Temescal Creek near Corona, State Gage Station Index No. 44-1

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—							
Feb. 16	[a]		7,500	April 19	F. W. Bush		1.4
1928—				April 25	F. W. Bush		1.5
Jan. 19	H. C. Troxell		2.1	May 3	F. W. Bush		1.1
Jan. 26	H. C. Troxell	.85	2.6	May 16	F. W. Bush		.9
Feb. 2	H. C. Troxell	.92	2.4	May 22	F. W. Bush		.9
Feb. 8	H. C. Troxell	.90	2.6	May 29	F. W. Bush		1.0
Feb. 15	H. C. Troxell	.90	2.7	June 5	F. W. Bush		.8
Feb. 23	H. C. Troxell	.90	1.9	June 12	F. W. Bush		.8
Feb. 29	H. C. Troxell	.92	1.9	June 19	F. W. Bush		.8
Mar. 9	H. C. Troxell	1.00	1.9	July 3	F. W. Bush		.7
Mar. 14	H. C. Troxell	1.00	1.8	July 19	F. W. Bush		.8
Mar. 21	H. C. Troxell		2.5	July 26	F. W. Bush		.7
Mar. 29	H. C. Troxell		1.6	Aug. 2	F. W. Bush		.6

[a] Field cross-sections from highwater marks by F. W. Bush. Computed from Kutter's formula, by J. A. Case.

Daily discharge in second-feet of Temescal Creek near Corona, State Gage Station Index No. 44–1

For the year ending September 30, 1928

Day	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1	2.5	2.4	1.9	1.2	1.1	1.0	.8	.7	.7
2	2.5	2.4	1.9	1.2	1.1	.9	.8	.6	.7
3	2.5	2.4	1.9	1.1	1.0	.9	.8	.6	.7
4	2.5	2.4	1.9	1.1	1.0	.8	.8	.6	.7
5	2.5	2.4	1.9	1.1	1.0	.8	.8	.6	.7
6	2.4	2.5	1.9	1.1	1.0	.8	.8	.6	.7
7	2.4	2.5	1.9	1.1	1.0	.8	.8	.6	.7
8	2.4	2.6	1.9	1.1	1.0	.8	.8	.6	.7
9	2.4	2.6	1.9	1.1	1.0	.8	.8	.6	.7
10	2.4	2.6	1.9	1.1	1.1	.8	.8	.6	.7
11	2.3	2.6	1.9	1.1	1.1	.8	.8	.6	.7
12	2.3	2.6	1.8	1.1	1.1	.8	.8	.6	.8
13	2.3	2.7	1.8	1.1	1.0	.8	.8	.6	.8
14	2.3	2.7	1.8	1.1	1.0	.8	.8	.6	.8
15	2.3	2.7	1.9	1.1	1.0	.8	.8	.6	.8
16	2.2	2.6	2.0	1.1	.9	.8	.8	.6	.8
17	2.2	2.6	2.1	1.1	.9	.8	.8	.6	.8
18	2.2	2.5	2.2	1.1	.9	.8	.8	.6	.8
19	2.1	2.4	2.3	1.1	.9	.8	.8	.6	.8
20	2.2	2.3	2.4	1.1	.9	.8	.8	.6	.8
21	2.4	2.2	2.5	1.1	.9	.8	.8	.6	.8
22	2.6	2.1	2.2	1.1	.9	.8	.8	.6	.8
23	2.6	1.9	2.0	1.1	.9	.8	.7	.6	.8
24	2.6	1.9	1.7	1.1	.9	.8	.7	.6	.8
25	2.6	1.9	1.5	1.1	.9	.8	.7	.7	.8
26	2.6	1.9	1.5	1.1	1.0	.8	.7	.7	.8
27	2.5	1.9	1.5	1.1	.9	.8	.7	.7	.8
28	2.5	1.9	1.4	1.1	.9	.8	.7	.7	.8
29	2.5	1.9	1.4	1.1	1.0	.8	.7	.7	.8
30	2.4	--------	1.5	1.1	1.0	.8	.7	.7	.8
31	2.4	--------	1.3	--------	1.0	--------	.7	.7	--------

Monthly discharge of Temescal Creek near Corona, State Gage Station Index No. 44–1

For the year ending September 30, 1928

Month, 1927–1928	Discharge in second-feet			Run-off in acre-feet
	Maximum	Minimum	Mean	
October	----------	----------	----------	[e]50
November	----------	----------	----------	[e]75
December	----------	----------	----------	[e]100
January	2.6	2.1	2.42	149
February	2.7	1.9	2.35	135
March	2.5	1.3	1.85	114
April	1.2	1.1	1.10	65
May	1.1	.9	.98	60
June	1.0	.8	.81	48
July	.8	.7	.77	47
August	.7	.6	.63	39
September	.8	.7	.76	45
The year	2.7	.6	1.28	927

[e] Estimated.

DRAINAGE DITCH ON IRVINE RANCH, ORANGE COUNTY, STATE GAGE STATION INDEX No. E–2

LOCATION.—Lane road, 2.2 miles southeast of Newport highway, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Monthly discharge record based on measurements made at regular intervals.

Discharge measurements of drainage ditch on Irvine Ranch, Orange County, State Gage Station Index No. E–2

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1927—				Feb. 17	J. Shiffer		1 5
Dec. 20	H. C. Troxell		1 0	Mar. 8	H. C. Troxell		1.5
1928—				Mar. 19	H. C. Troxell		3.2
Jan. 10	H. C. Troxell		2.2	Mar. 30	H. C. Troxell		1.6
Jan. 27	H. C. Troxell		1.2	June 6	J. Shiffer		3.6
Feb. 10	J. Shiffer		1.2	Sept. 26	H. C. Troxell		.3

Monthly discharge of drainage ditch on Irvine Ranch, Orange County, State Gage Station Index No. E–2

For the year ending September 30, 1928

Month	Mean discharge second-feet	Run-off in acre-feet	Month	Mean discharge second-feet	Run-off in acre-feet
October	.7	e43	May	2 0	123
November	.7	e42	June	2.0	123
December	1 0	61	July	.5	30
January	1.8	111	August	.5	30
February	2 5	139	September	.5	30
March	2.5	154			
April	2.5	149	The year	1.43	1,035

e Estimated.

DRAINAGE DITCH ON IRVINE RANCH, ORANGE COUNTY, STATE GAGE STATION INDEX No. E–3

LOCATION.—On Lane road, 2.0 miles southeast of Newport highway, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—No measurements made during period.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Monthly discharge record based on estimates of discharge made at regular intervals.

Monthly discharge of drainage ditch on Irvine Ranch, Orange County, State Gage Station Index No. E–3

For the year ending September 30, 1928

Month	Mean discharge second-feet	Run-off in acre-feet	Month	Mean discharge second-feet	Run-off in acre-feet
October	.1	e6.1	May	.1	e6 1
November	.1	e6 0	June	.1	e6.0
December	.2	e12 3	July	.1	e6.1
January	.3	e18.4	August	.1	e6.1
February	.5	e27.8	September	.1	e6.0
March	.3	e18.4			
April	.2	e11.9	The year	.18	132.0

e Estimated.

DRAINAGE DITCH NEAR FAIRVIEW, STATE GAGE STATION INDEX No. E–4

LOCATION.—On Newport highway, ¾ mile southwest of Paularino, near Fairview, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Monthly discharge record based on measurements made at regular intervals.

Discharge measurements of drainage ditch near Fairview, State Gage Station Index No. E–4

For the year ending September 30, 1928

Date	Made by	Discharge second-feet	Date	Made by	Discharge second-feet
1927—			Feb. 10	J. Shiffer	3.0
Dec. 8	H. C. Troxell	.7	Feb. 17	J. Shiffer	2.0
Dec. 23	H. C. Troxell	1.1	Mar. 8	H. C. Troxell	3.2
1928—			Mar. 19	J. Shiffer	2.2
Jan. 5	H. C. Troxell	1.1	Mar. 30	H. C. Troxell	1.8
Jan. 20	H. C. Troxell	1.7	June 6	J. Shiffer	1.6
Jan. 27	H. C. Troxell	1.4	Sept. 26	H. C. Troxell	[e].4

Monthly discharge of drain ditch near Fairview, State Gage Station Index No. E-4

Month	Mean discharge second-feet	Run-off in acre-feet	Month	Mean discharge second-feet	Run-off in acre-feet
October	.6	[e]36.9	May	1.7	104.0
November	.6	[e]35.7	June	1.0	60.0
December	.9	53.3	July	.8	49.0
January	1.4	86.1	August	.5	31.0
February	4.0	230.0	September	.5	30.0
March	2.4	148.0			
April	1.8	107.0	The year	1.35	970.0

[e] Estimated

DRAINAGE DITCH NEAR FAIRVIEW, STATE GAGE STATION INDEX No. E–5

LOCATION.—On Adams avenue, ¼ mile east of the Santa Ana River, near Fairview, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Monthly discharge record based on measurements made at regular intervals.

Discharge measurements of drainage ditch near Fairview, State Gage Station Index No. E–5

For the year ending September 30, 1928

Date	Made by	Discharge second-feet	Date	Made by	Discharge second-feet
1927—			Feb. 10	J. Shiffer	1.8
Dec. 8	H. C. Troxell	1.1	Feb. 17	J. Shiffer	1.9
Dec. 23	H. C. Troxell	1.6	Mar. 8	H. C. Troxell	2.3
1928—			Mar. 19	J. Shiffer	3.3
Jan. 5	H. C. Troxell	1.7	Mar. 30	H. C. Troxell	2.3
Jan. 20	H. C. Troxell	1.8	June 6	J. Shiffer	1.3
Jan. 27	H. C. Troxell	1.7	Sept. 26	H. C. Troxell	[e].2
Feb. 3	H. C. Troxell	2.2			

[e] Estimated.

Monthly discharge of drainage ditch near Fairview, State Gage Station Index No. E–5
For the year ending September 30, 1928

Month	Mean discharge second-feet	Run-off in acre-feet	Month	Mean discharge second-feet	Run-off in acre-feet
October	.5	[e]31.0	May	1.5	92.0
November	.5	[e]30.0	June	1.0	60.0
December	1.4	80.0	July	.5	31.0
January	1.7	104.0	August	.5	31.0
February	2.0	115.0	September	.3	18.0
March	2.6	160.0			
April	2.0	119.0	The year	1.21	871.0

[e] Estimated.

DRAINAGE DITCH NEAR TALBERT, STATE GAGE STATION INDEX No. E–6

LOCATION.—On Adams avenue, ½ mile west of the Santa Ana River, near Talbert, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Monthly discharge record based on measurements made at regular intervals.

Discharge measurements of drainage ditch near Talbert, State Gage Station Index No. E–6
For the year ending September 30, 1928

Date	Made by	Discharge second-feet	Date	Made by	Discharge second-feet
1927—			Feb. 10	J. Shiffer	1.7
Dec. 8	H. C. Troxell	.5	Feb. 17	J. Shiffer	1.5
Dec. 10	H. C. Troxell	2.9	Mar. 8	H. C. Troxell	1.6
1928—			Mar. 19	J. Shiffer	.9
Jan. 5	H. C. Troxell	1.3	Mar. 30	H. C. Troxell	.4
Jan. 20	H. C. Troxell	2.0	June 6	J. Shiffer	.2
Jan. 27	H. C. Troxell	2.0	Sept. 26	H. C. Troxell	Dry
Feb. 3	H. C. Troxell	2.4			

Monthly discharge of drainage ditch near Talbert, State Gage Station Index No. E–6
For the year ending September 30, 1928

Month	Mean discharge second-feet	Run-off in acre-feet	Month	Mean discharge second-feet	Run-off in acre-feet
October	.5	[e]31.0	May	.3	18.0
November	.5	[e]30.0	June	.2	12.0
December	2.0	123.0	July	.2	12.0
January	2.0	123.0	August	.1	6.0
February	1.8	104.0	September	0	0
March	1.0	62.0			
April	.4	24.0	The year	.75	545.0

DRAINAGE DITCH NEAR TALBERT, STATE GAGE STATION INDEX No. E–7

LOCATION.—On Adams avenue, 1 mile west of Santa Ana River and 2 miles south of Talbert, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—No measurements made during period.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Monthly discharge record based on estimates of discharge made at regular intervals.

Monthly discharge of drainage ditch near Talbert,
State Gage Station Index No. E–7
For the year ending September 30, 1928

Month	Mean discharge second-feet	Run-off in acre-feet	Month	Mean discharge second-feet	Run-off in acre-feet
October	0	0	May	0	0
November	0	0	June	0	0
December	0	0	July	0	0
January	.1	[e]6.1	August	0	0
February	.2	[e]12.0	September	0	0
March	.2	[e]12.0			
April	.1	[e]6.0	The year	.05	36.0

[e] Estimated.

DRAINAGE DITCH NEAR TALBERT, STATE GAGE STATION INDEX No. E–8

LOCATION.—On Adams avenue, 1½ miles west of the Santa Ana River.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Monthly discharge record based on measurements made at regular intervals.

Discharge measurements of drainage ditch near Talbert,
State Gage Station Index No. E–8
For the year ending September 30, 1928

Date	Made by	Discharge second-feet	Date	Made by	Discharge second-feet
1927—			Feb. 3	H. C. Troxell	.3
Dec. 9	H. C. Troxell	.1	Feb. 10	J. Shiffer	.4
Dec. 10	H. C. Troxell	.4	Feb. 17	J. Shiffer	.4
Dec. 23	H. C. Troxell	.3	Mar. 8	H. C. Troxell	.9
1928—			Mar. 19	J. Shiffer	.9
Jan. 5	H. C. Troxell	.4	Mar. 30	H. C. Troxell	.3
Jan. 20	H. C. Troxell	1.3	June 6	J. Shiffer	.1
Jan. 27	H. C. Troxell	.4	Sept. 26	H. C. Troxell	0

Monthly discharge of drainage ditch near Talbert,
State Gage Station Index No. E–8
For the year ending September 30, 1928

Month	Mean discharge second-feet	Run-off in acre-feet	Month	Mean discharge second-feet	Run-off in acre-feet
October	.1	[e]6.0	May	.2	12.0
November	.1	[e]6.0	June	.1	6.0
December	.3	18.0	July	.1	6.0
January	.7	43.0	August	.1	6.0
February	.4	23.0	September	0	0
March	.7	43.0			
April	.2	12.0	The year	.25	176.0

DRAINAGE DITCH NEAR TALBERT, STATE GAGE STATION INDEX No. E–9

LOCATION.—On Adams avenue, 2 miles west of Santa Ana River, near Talbert, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Monthly discharge record based on measurements made at regular intervals.

Discharge measurements of drainage ditch near Talbert, State Gage Station Index No. E–9

For the year ending September 30, 1928

Date	Made by	Discharge second-feet	Date	Made by	Discharge second-feet
1927—			Feb. 3	H. C. Troxell	2.4
Dec. 9	H. C. Troxell	1.0	Feb. 10	H. C. Troxell	2.1
Dec. 10	H. C. Troxell	2.1	Feb. 17	J. Shiffer	2.0
Dec. 23	H. C. Troxell	2.2	Mar. 8	H. C. Troxell	2.2
1928—			Mar. 19	J. Shiffer	1.4
Jan. 5	H. C. Troxell	1.5	Mar. 30	H. C. Troxell	1.2
Jan. 20	H. C. Troxell	1.2	June 6	J. Shiffer	1.0
Jan. 27	H. C. Troxell	2.2	Sept. 26	H. C. Troxell	[e].4

Monthly discharge of drainage ditch near Talbert, State Gage Station Index No. E–9

For the year ending September 30, 1928

Month	Mean discharge second-feet	Run-off in acre-feet	Month	Mean discharge second-feet	Run-off in acre-feet
October	.8	[e]49.0	May	1.2	74.0
November	.9	[e]54.0	June	1.0	60.0
December	1.6	98.0	July	.7	43.0
January	1.6	98.0	August	.6	37.0
February	2.2	126.0	September	.4	24.0
March	1.7	104.0			
April	1.5	89.0	The year	1.18	836.0

DRAINAGE DITCH NEAR WINTERSBURG, STATE GAGE STATION INDEX No. E–10

LOCATION.—On Wintersburg avenue, ¾ mile west of Wintersburg, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Monthly discharge record based on discharge measurements made at regular intervals.

Discharge measurements of drainage ditch near Wintersburg, State Gage Station Index No. E–10

For the year ending September 30, 1928

Date	Made by	Discharge second-feet	Date	Made by	Discharge second-feet
1927—			Feb. 10	H. C. Troxell	2.4
Dec. 9	H. C. Troxell	1.0	Feb. 17	J. Shiffer	2.4
Dec. 23	H. C. Troxell	2.1	Mar. 8	H. C. Troxell	2.8
1928—			Mar. 19	J. Shiffer	2.5
Jan. 5	H. C. Troxell	1.9	Mar. 30	H. C. Troxell	2.6
Jan. 27	H. C. Troxell	1.8	June 6	J. Shiffer	.8
Feb. 3	H. C. Troxell	2.2	Sept. 26	H. C. Troxell	[e].3

[e] Estimated.

Monthly discharge of drainage ditch near Wintersburg, State Gage Station Index No. E–10

For the year ending September 30, 1928

Month	Mean discharge second-feet	Run-off in acre-feet	Month	Mean discharge second-feet	Run-off in acre-feet
October	1.0	[a]61.0	May	1.5	92.0
November	1.0	[a]60.0	June	.8	48.0
December	1.7	104.0	July	.5	31.0
January	1.9	117.0	August	.4	25.0
February	2.3	132.0	September	.3	18.0
March	2.6	160.0			
April	2.2	131.0	The year	1.35	979.0

[a] Estimated.

DRAINAGE DITCH NEAR WINTERSBURG, STATE GAGE STATION INDEX No. E–11

LOCATION.—On Wintersburg avenue, 2 miles west of Wintersburg, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—Made by wading.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Monthly discharge record based on measurements made at regular intervals.

Discharge measurements of drainage ditch near Wintersburg, State Gage Station Index No. E–11

For the year ending September 30, 1928

Date	Made by	Discharge second-feet	Date	Made by	Discharge second-feet
1927—			Feb. 10	J. Shiffer	1.9
Dec. 9	H. C. Troxell	1.4	Feb. 17	J. Shiffer	2.0
Dec. 23	H. C. Troxell	2.3	Mar. 8	H. C. Troxell	5.2
1928—			Mar. 19	J. Shiffer	3.2
Jan. 5	H. C. Troxell	3.4	Mar. 30	H. C. Troxell	3.4
Jan. 27	H. C. Troxell	2.0	June 6	J. Shiffer	2.0
Feb. 3	H. C. Troxell	2.5	Sept. 26	H. C. Troxell	.6

Monthly discharge of drainage ditch near Wintersburg, State Gage Station Index No. E–11

For the year ending September 30, 1928

Month	Mean discharge second-feet	Run-off in acre-feet	Month	Mean discharge second-feet	Run-off in acre-feet
October	1.0	[a]61.0	May	2.0	123.0
November	1.0	[a]60.0	June	1.5	90.0
December	1.9	117.0	July	1.0	61.0
January	2.7	166.0	August	.8	49.0
February	2.1	121.0	September	.6	36.0
March	3.9	240.0			
April	2.5	149.0	The year	1.75	1,270.0

DRAINAGE DITCH NEAR WINTERSBURG, STATE GAGE STATION INDEX No. E-12

LOCATION.—On Bolsa Chica road, 0.4 miles south of Smeltzer avenue, near Wintersburg, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—No measurements made during period.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Monthly discharge record based on estimates of discharge made at regular intervals.

Monthly discharge of drainage ditch near Wintersburg, State Gage Station Index No. E–12

For the year ending September 30, 1928

Month	Mean discharge second-feet	Run-off in acre-feet	Month	Mean discharge second-feet	Run-off in acre-feet
October	.1	[e]6.1	May	.1	[e]6.1
November	.1	[e]6.0	June	.1	[e]6.0
December	.2	[e]12.3	July	.1	[e]6.1
January	.2	[e]12.3	August	.1	[e]6.1
February	.3	[e]17.3	September	.1	[e]6.0
March	.2	[e]12.3			
April	.2	[e]11.9	The year	.15	108 0

[e] Estimated.

DRAINAGE DITCH NEAR LOS ALAMITOS, STATE GAGE STATION INDEX No. E-13

LOCATION.—On private road, ½ mile south of Westminster avenue and ¼ mile west of Bolsa Chica street, near Los Alamitos, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—No measurements made during period.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Ditch dry during entire period.

DRAINAGE DITCH NEAR LOS ALAMITOS, STATE GAGE STATION INDEX No. E–14

LOCATION.—On private road, ½ mile south of Westminster avenue and 1 mile west of Bolsa Chica street, near Los Alamitos, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—No measurements made during period.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Ditch dry during entire period.

DRAINAGE DITCH NEAR LOS ALAMITOS, STATE GAGE STATION INDEX No. E-15

LOCATION.—At corner of Westminster avenue and Los Alamitos boulevard, near Los Alamitos, Orange County.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

DISCHARGE MEASUREMENTS.—No measurements made during period.

CHANNEL AND CONTROL.—Ditch channel; no well-defined control.

ACCURACY.—Ditch dry during entire period.

UPPER CARBON CANYON NEAR OLINDA, STATE GAGE STATION INDEX No. 49–2

LOCATION.—In SE¼ of Sec. 2, T. 3 S., R. 9 W., 2 miles east of Olinda on Carbon Canyon road, Orange County.

DRAINAGE AREA.—5.2 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage.

DISCHARGE MEASUREMENTS.—Made by wading.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 0.80 ft., February 4, 1928 (discharge, 9.5 sec.-ft.).

ACCURACY.—Estimated from measurements by Orange County Flood Control.

COOPERATION.—Orange County Flood Control.

Discharge measurements of Upper Carbon Canyon near Olinda, State Gage Station Index No. 49–2

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1928—				Feb. 4	Stoner	.69	5.0
Feb. 4	Stoner	.80	9.5	Mar. 6	Stoner	.55	.5

Monthly discharge of Upper Carbon Canyon near Olinda, State Gage Station Index No. 49–2

For the year ending September 30, 1928

Month	Run-off in acre-feet	Month	Run-off in acre-feet
October	3	May	3
November	8	June	3
December	10	July	3
January	3	August	3
February	12	September	3
March	5		
April	3	The year	59

LOWER CARBON CANYON NEAR OLINDA, STATE GAGE STATION INDEX No. 49–1

LOCATION.—In SE¼, Sec. 8, T. 3 S., R. 9 W., on Rose street, ¼ mile south of Olinda, Orange County.

DRAINAGE AREA.—12.6 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage.

DISCHARGE MEASUREMENTS.—Made by wading.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 0.50 ft., February 4, 1928 (discharge, 2.8 sec.-ft.); dry during remainder of season.

ACCURACY.—Estimated from measurements by Orange County Flood Control.

COOPERATION.—Orange County Flood Control.

Discharge measurements of Lower Carbon Canyon near Olinda, State Gage Station Index No. 49–1

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1928— Feb. 4	Stoner	.50	2.8	Feb. 4	Stoner	.45	.7

Monthly discharge of Lower Carbon Canyon near Olinda, State Gage Station Index No. 49–1

For the year ending September 30, 1928

Month	Run-off in acre-feet	Month	Run-off in acre-feet
October	0	May	0
November	0	June	0
December	0	July	0
January	0	August	0
February	2.0	September	0
March	0		
April	0	The year	2.0

FOOTHILL DRAIN NEAR PLACENTIA, STATE GAGE STATION INDEX No. E-16

LOCATION.—In NW¼. Sec. 25, T. 3 S., R. 10 W., 1½ miles north of A., T. and S. F. R. R. on extension of Placentia avenue, and 1 mile northwest of Placentia, Orange County.

DRAINAGE AREA.—Not measured.

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage.

EXTREMES OF DISCHARGE.—Maximum discharge, 0.8 sec.-ft., February 4, 1928.

ACCURACY.—Estimated from measurements by Orange County Flood Control.

COOPERATION.—Orange County Flood Control.

Discharge measurements of Foothill Drain near Placentia, State Gage Station Index No. E-16

For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1928— Feb. 4	Stoner	.65	.8	Mar. 6	Stoner	.90	.8

Monthly discharge of Foothill Drain near Placentia,
State Gage Station Index No. E-16
For the year ending September 30, 1928

Month	Run-off in acre-feet	Month	Run-off in acre-feet
October	1.0	May	0
November	0	June	0
December	1.2	July	0
January	0	August	0
February	1.6	September	0
March	1.2		
April	0	The year	5.0

SOUTH FORK OF BREA CANYON NEAR BREA, STATE GAGE STATION INDEX No. 48-1

LOCATION.—In SE¼ of Sec. 1, T. 3 S., R. 10 W., 1½ miles north of Brea, on Brea Canyon road, in Orange County.

DRAINAGE AREA.—12.0 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage.

DISCHARGE MEASUREMENTS.—Made by wading.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 1.00 ft., March 6, 1928 (discharge, 8.0 sec.-ft.).

ACCURACY—Estimated from measurements by Orange County Flood Control.

COOPERATION.—Orange County Flood Control.

Discharge measurements of South Fork of Brea Canyon near Brea,
State Gage Station Index No. 48-1
For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1928—							
Feb. 4	Stoner	.50	5.1	Mar. 6	Stoner	1.00	8.0
Feb. 4	Stoner	.10	2.0	Mar. 6	Stoner	.20	2.5

Monthly discharge of South Fork of Brea Canyon near Brea,
State Gage Station Index No. 48-1
For the year ending September 30, 1928

Month	Run-off in acre-feet	Month	Run-off in acre-feet
October	6.0	May	6.0
November	10.0	June	6.0
December	6.0	July	6.0
January	6.0	August	6.0
February	30.0	September	6.0
March	15.0		
April	6.0	The year	109.0

NORTH FORK OF BREA CANYON NEAR BREA, STATE GAGE STATION INDEX No. 47-1

LOCATION.—In NE¼ of Sec. 1, T. 3 S., R. 10 W., on Brea Canyon road, 1½ miles northeast of Brea, Orange County.

DRAINAGE AREA.—7.8 square miles (measured on topographic map).

RECORDS AVAILABLE.—October 1, 1927, to September 30, 1928.

GAGE.—Staff gage.

DISCHARGE MEASUREMENTS.—Made by wading.

EXTREMES OF DISCHARGE.—Maximum stage recorded, 0.90 ft., March 6, 1928 (discharge, 2.0 sec.-ft.).

ACCURACY.—Discharge estimated from measurements by Orange County Flood Control.

COOPERATION.—Orange County Flood Control.

Discharge measurements of North Fork of Brea Canyon near Brea, State Gage Station Index No. 47-1
For the year ending September 30, 1928

Date	Made by	Gage height feet	Discharge second-feet	Date	Made by	Gage height feet	Discharge second-feet
1928—							
Feb. 4	Stoner	.80	1.5	Mar. 6	Stoner	.90	2.0
Feb. 4	Stoner	.60	.6	Mar. 6	Stoner	.65	.8

Monthly discharge of North Fork of Brea Canyon near Brea, State Gage Station Index No. 47-1
For the year ending September 30, 1928

Month	Run-off in acre-feet	Month	Run-off in acre-feet
October	3	May	3
November	3	June	3
December	4	July	3
January	3	August	3
February	5	September	3
March	6		
April	3	The year	42

CHAPTER 3

SANTA ANA RIVER AT PRADO AND AT PEDLEY BRIDGE

Compilation of Summer Measurements July, August and September

From time to time numerous current-meter measurements of the Santa Ana River have been made at various points. Beginning with the year 1878 the flow at the diversion box of the Santa Ana Valley Irrigation and Anaheim Union Water companies have been measured at irrregular intervals. In 1919 the U. S. Geological Survey established a gaging station near this point.

At Pedley Bridge and at "Riverside Narrows" various measurements have been made since 1888. In 1919 the U. S. Geological Survey began a systematic series of measurements.

The following notations have been used in the accompanying tables:

A—From documents accompanying canceled application No. 74, Division of Water Rights, compiled from measurements made by H. C. Kellogg and others.

B—The actual monthly discharge at Prado gaging station obtained by U. S. Geological Survey.

D—From reports of H. C. Kellogg.

E—Based on measurements made by U. S. Geological Survey in vicinity of Pedley Bridge and a comparison of those measurements to run-off at Prado.

F—Measurements published by U. S. Geological Survey.

G—From record of Santa Ana River at Pedley Bridge, Santa Ana Investigation.

Santa Ana River at division box of Santa Ana Valley Irrigation and Anaheim Union Water companies; one mile below U. S. G. S. station at Prado, and practically identical with it in discharge; after July, 1919, at U. S. G. S. station at Prado.

Date	Number of measurements	Mean discharge in second-feet of measurements	Estimated monthly run-off in acre-feet	Authority
July, 1878	1	36	2,210	A
August, 1879	1	31	1,910	A
August, 1880	1	28	1,720	A
July, 1891	1	49	3,010	A
August, 1891	7	47	2,890	A
September, 1891	2	39	2,320	A
July, 1892	10	64	3,940	A
August, 1892	31	64	3,940	A
September, 1892	18	64	3,810	A
July, 1896	22	59	3,510	A
August, 1896	6	60	3,570	A
August, 1900	31	51	3,080	A
September, 1900	14	61	3,630	A
July, 1901	6	54	3,320	A
August, 1901	27	63	3,870	A
September, 1901	20	60	3,570	A
July, 1902	1	60	3,690	A
September, 1902	1	42	2,500	A
July, 1904	1	48	2,950	A
September, 1904	1	66	3,930	A
September, 1905	1	66	3,930	A
July, 1906	2	58	3,570	A
September, 1906	1	69	4,110	A
July, 1907	2	51	3,140	A

Santa Ana River at division box of Santa Ana Valley Irrigation and Anaheim Union Water companies; one mile below U. S. G. S. station at Prado, and practically identical with it in discharge; after July, 1919, at U. S. G. S. station at Prado—Continued.

Date	Number of measurements	Mean discharge in second-feet of measurements	Estimated monthly run-off in acre-feet	Authority
August, 1907	24	49	3,010	A
September, 1907	25	56	3,330	A
August, 1908	33	47	2,890	A
September, 1908	24	51	3,030	A
July, 1909	3	66	4,060	A
August, 1909	1	52	3,200	A
July, 1910	1	53	3,260	A
August, 1910	2	49	3,010	A
July, 1916	1	83	5,100	A
August, 1916	5	69	4,240	A
September, 1916	1	62	3,690	A
July, 1917	5	62	3,810	A
August, 1917	2	59	3,630	A
September, 1917	2	52	3,100	A
July, 1919			3,480	B
August, 1919			3,620	B
September, 1919			4,700	B
July, 1920			3,920	B
August, 1920			3,580	B
September, 1920			4,770	B
July, 1921			4,810	B
August, 1921			4,470	B
September, 1921			4,520	B
July, 1922			6,700	B
August, 1922			4,510	B
September, 1922			3,820	B
July, 1923			4,100	B
August, 1923			4,220	B
September, 1923			4,770	B
July, 1924			3,760	B
August, 1924			3,420	B
September, 1924			3,950	B
July, 1925			3,510	B
August, 1925			3,500	B
September, 1925			3,830	B
July, 1926			3,550	B
August, 1926			3,250	B
September, 1926			3,480	B
July, 1927			3,290	B
August, 1927			3,140	B
September, 1927			3,340	B
July, 1928			2,580	B
August, 1928			2,340	B
September, 1928			2,530	B

Santa Ana River at Pedley Bridge or Riverside Narrows

Date	Number of measurements	Mean discharge in second-feet of measurements	Estimated monthly run-off in acre-feet	Authority
July, 1888	2	10	615	F
August, 1888	1	8.5	523	F
September, 1888	1	9.5	565	F
August, 1889	1	11	676	F
September, 1889	1	11	666	F
August, 1890	1	19	1,170	F
September, 1891	1	16	952	F
September, 1892	1	29	1,730	F
September, 1899	1	40	2,380	F
July, 1900	1	38	2,340	F
July, 1901	4	39	2,400	D
August, 1901	4	40	2,460	D
September, 1901	1	40	2,380	D
August, 1903	1	41	2,520	D
August, 1904	1	30	1,840	D
August, 1905	1	30	1,840	D
September, 1905	21	39	2,300	D
July, 1907	4	38	2,340	D
August, 1907	4	30	1,840	D
September, 1907	4	32	1,900	D
July, 1908	2	26	1,540	D
August, 1908	6	29	1,780	D
September, 1908	4	33	2,020	D
July, 1909	1	37	2,280	D
July, 1910	3	33	2,030	D
September, 1910	1	27	1,610	D
July, 1916	1	54	3,320	D
August, 1916	4	44	2,700	D
September, 1916	1	35	2,080	D
July, 1919	5	39	2,400	E
August, 1919	4	39	2,400	E
September, 1919	3	44	2,620	E
July, 1920	2	44	2,700	E
August, 1920	4	44	2,700	E
September, 1920	3	44	2,620	E
July, 1921	4	44	2,700	E
August, 1921	4	44	2,640	E
September, 1921	3	47	2,620	E
July, 1922	3	77	5,230	E
August, 1922	3	53	3,380	E
September, 1922	4	43	2,560	E
July, 1923	4	37	2,280	E
August, 1923	4	42	2,340	E
September, 1923	2	47	2,680	E
July, 1924	3	38	2,280	E
August, 1924	5	42	2,520	E
September, 1924	3	42	2,560	E
July, 1925	3	42	2,770	E
August, 1925	2	44	2,640	E
September, 1925	4	41	2,440	E
July, 1926	4	41	2,460	E
August, 1926	2	37	2,340	E
September, 1926	2	41	2,440	E
July, 1927	3	36	1,970	E
August, 1927	2	32	1,970	E
September, 1927	2	31	1,960	E
July, 1928	-------	38	2,320	G
August, 1928	-------	33	2,040	G
September, 1928	-------	32	1,920	G

Summary known and estimated three months summer flow of Santa Ana River at division box of Santa Ana Valley Irrigation and Anaheim Union Water Companies, after 1919, at U. S. G. S. station at Prado.

Year	July, acre-feet	August, acre-feet	September, acre-feet	Total, acre-feet
1878	2,210	----------	----------	6,600
1879	----------	1,910	----------	6,000
1880	----------	1,720	----------	5,500
1891	3,010	2,890	2,320	8,200
1892	3,940	3,940	3,810	11,700
1896	3,510	3,570	----------	10,600
1900	----------	3,080	3,630	10,200
1901	3,320	3,870	3,570	10,800
1902	3,690	----------	2,500	9,200
1904	2,950	----------	3,930	10,000
1905	----------	----------	3,930	10,000
1906	3,570	----------	4,110	10,700
1907	3,140	3,010	3,330	9,500
1908	----------	3,890	3,030	9,000
1909	4,060	3,200	----------	10,300
1910	3,260	3,010	----------	9,000
1916	5,100	4,240	3,690	13,000
1917	3,810	3,630	3,100	10,500
1919	3,480	3,620	4,700	11,800
1920	3,920	3,580	4,770	12,300
1921	4,810	4,470	4,520	13,800
1922	6,700	4,510	3,820	15,000
1923	4,100	4,220	4,770	13,100
1924	3,760	3,420	3,950	11,100
1925	3,510	3,500	3,830	10,800
1926	3,550	3,250	3,480	10,300
1927	3,290	3,140	3,340	9,800
1928	2,580	2,340	2,530	7,450

Summary known and estimated three months summer flow of Santa Ana River at Pedley Bridge or Riverside Narrows

Year	July, acre-feet	August, acre-feet	September, acre-feet	Total acre-feet
1888	1,615	523	565	1,700
1889	----------	676	666	2,000
1890	----------	1,170	----------	3,500
1891	----------	----------	952	4,000
1892	----------	----------	1,730	7,000
1899	----------	----------	2,380	8,000
1900	2,340	----------	----------	6,800
1901	2,400	2,460	2,380	7,200
1903	----------	2,520	----------	7,500
1904	----------	1,840	----------	6,000
1905	----------	1,840	2,300	6,100
1907	2,340	1,840	1,900	6,100
1908	1,540	1,780	2,020	5,300
1909	2,280	----------	----------	6,000
1910	2,030	1,610	----------	5,100
1916	3,320	2,700	2,080	8,100
1919	2,400	2,400	2,620	7,400
1920	2,700	2,700	2,620	8,000
1921	2,700	2,640	2,620	8,000
1922	5,230	3,380	2,560	11,200
1923	2,280	2,340	2,680	7,300
1924	2,280	2,520	2,560	7,400
1925	2,770	2,640	2,440	7,800
1926	2,460	2,340	2,440	7,200
1927	1,970	1,970	1,960	5,900
1928	2,320	2,040	1,920	6,280

Comparison of three months summer flow of the Santa Ana River at Prado and Pedley Bridge in acre-feet

(The difference represents inflow from Cucamonga and Temescal Basin.)

Year	Pedley Bridge	Prado	Difference	Year	Pedley bridge	Prado	Difference
1878		6,600		1907	6,100	9,500	3,400
1879		6,000		1908	5,300	9,000	3,700
1880		5,500		1909	6,000	10,300	4,300
1888	1,700			1910	5,100	9,000	3,900
1889	2,000			1916	8,100	13,000	4,900
1890	3,500			1917		10,500	
1891	4,000	8,200	4,200	1919	7,400	11,800	4,400
1892	7,000	11,700	4,700	1920	8,000	12,300	4,300
1896		10,600		1921	8,000	13,800	5,800
1899	8,000			1922	11,200	15,000	3,800
1900	6,800	10,200	3,400	1923	7,300	13,100	5,800
1901	7,200	10,800	3,600	1924	7,400	11,100	3,700
1902		9,200		1925	7,800	10,800	3,000
1903	7,500			1926	7,200	10,300	3,100
1904	6,000	10,000	4,000	1927	5,900	9,800	3,900
1905	6,100	10,000	3,900	1928	6,280	7,450	1,170
1906		10,700					

63685 7-29 2000

COLTON
Loma Linda
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING & IRRIGATION
EDWARD HYATT - STATE ENGINEER
SAN BERNARDINO
RIVERSIDE
ORANGE
SANTA ANA RIVER
SHEET Nº 1
SCALE
1928
ELEVATION IN FEET
2000
1500
1000
500
E. ST. BRIDGE
SB-151
SB-153
SB-154
SB-152
SANTA FE R R BRIDGE
TIPPECANOE ST BRIDGE
PACIFIC ELECTRIC R R BRIDGE
RECENT ALLUVIUM
OLD ALLUVIUM
13
12
11
10
9
8
7
DISTANCE

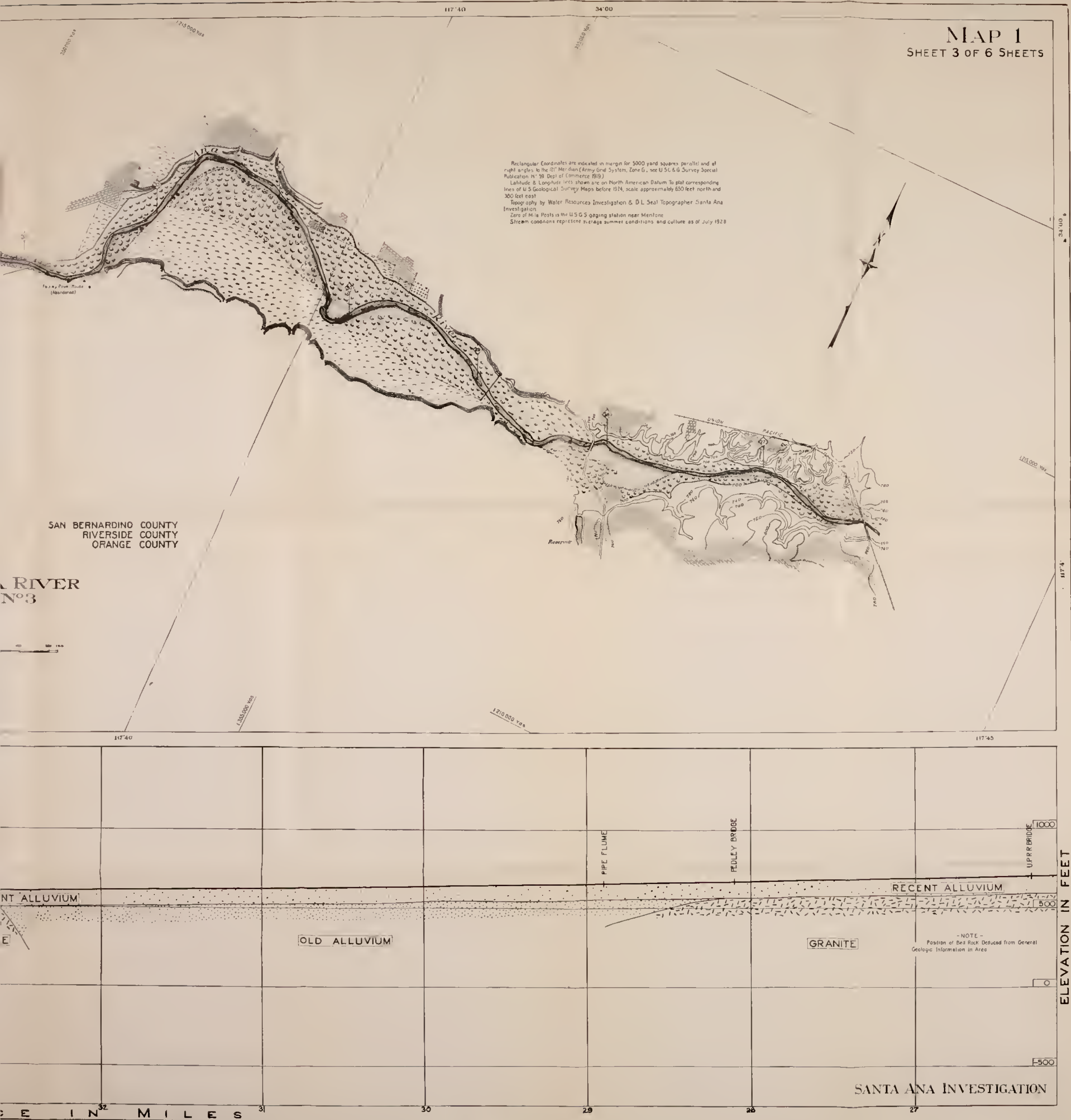
63665


MAP 1
SHEET 1 OF 6 SHEETS
Rectangular Coordinates are indicated in margin for 5000 yard squares parallel and at right angles to the 121° Meridian (Army Grid System, Zone G, see U.S.C.&G. Survey Special Publication Nº 59, Dept of Commerce 1919)
Latitude and Longitude lines shown are on North American Datum. To plot corresponding lines of U.S. Geological Survey Maps before 1924 scale approximately 650 feet north and 380 feet east
Topography by Los Angeles Water Dept & D.L. Seal Topographer for Santa Ana Investigation
Zero of Mile Posts is the U.S.G.S. gaging station near Mentone
Stream conditions represent average summer conditions and culture as of July 1928
East Highland
Aplin
Plunge
Creek
Oak Canyon
Santa Ana Canyon
Mill Creek
Mile Post
U.S.G.S. Gage
Power House Nº 3
Check Dams
NARDINO COUNTY
VERSIDE COUNTY
ORANGE COUNTY
SAN BERNARDINO AVE.
ORANGE ST. BRIDGE
SANTA FE R.R. BRIDGE
ALLUVIUM
LUVIUM
GRANITE
-NOTE-
Position of Bed Rock Deduced from General Geologic Information in Area
2000
1500
1000
500
ELEVATION IN FEET
E IN MILES
SANTA ANA INVESTIGATION

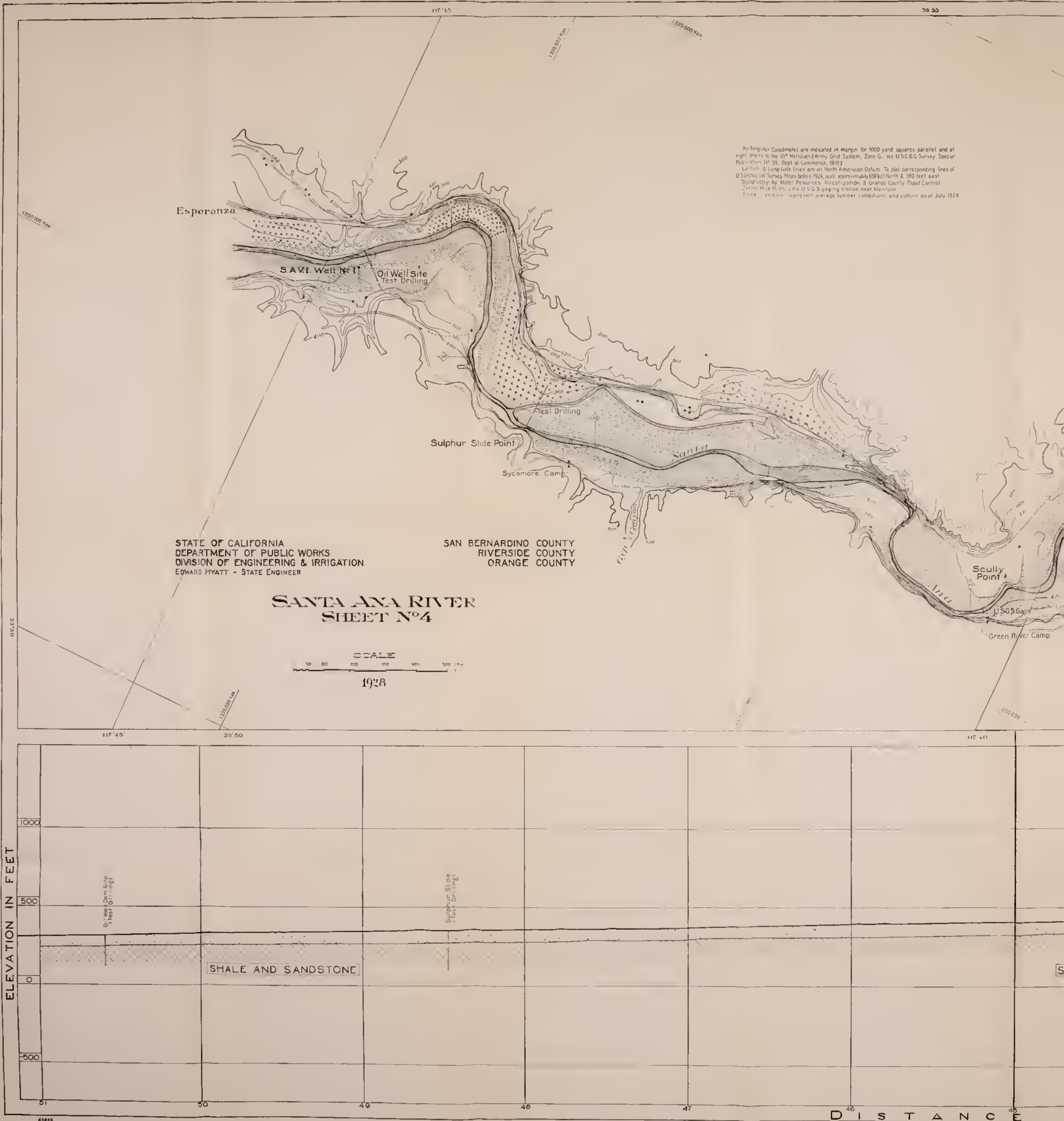

Rectangular Coordinates are indicated in margin for 5000 yard squares parallel and at right angles to the 121° Meridian (Army Grid System, Zone G; see U.S.C.&G. Survey Special Publication N° 59, Dept of Commerce 1919)
Latitude and Longitude lines shown are on North American Datum. To plot corresponding lines of U.S. Geological Survey Maps before 1924, scale approximately 650 feet north and 360 feet east
Topography by Los Angeles Water Dept.-Water Resources Investigation; A.C. Fulmor, County Surveyor of Riverside County & D.L. Seal, Topographer Santa Ana Investigation.
Zero of Mile Posts is the U.S.G.S. gaging station near Mentone
Stream conditions represent average summer conditions and culture as of July 1928
117°30'
34°00'
MISSION
BOULEVARD
Reservoir
117°25'
ELEVATION IN FEET
1000
500
0
-500
RUBIDOUX BRIDGE-MISSION ROAD
P.E.R.R. BRIDGE
GRANITE
OLD ALLUVIUM
GRANITE
RECEN
26
25
24
23
22
21
20
DISTANCE I
63C85

MAP 1
SHEET 2 OF 6 SHEETS
COLTON
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING & IRRIGATION
EDWARD HYATT – STATE ENGINEER
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
SANTA ANA RIVER
SHEET Nº 2
SCALE
1928
RIVERSIDE
Rubidoux Mt
JURUPA
STREET
TURBINE ST
BOULEVARD
RIALTO ROAD
JURUPA FLUME
SANTA FE R.R. BRIDGE
P.E. AND S.P.R.R. BRIDGE
RIVERSIDE WATER CO CANAL
MT VERNON AVE BRIDGE
S.P.R.R. BRIDGE
1000
500
0
-500
RECENT ALLUVIUM
OLD ALLUVIUM
-NOTE-
Position of Bed Rock Deduced from General Geologic Information in Area
ELEVATION IN FEET
E IN MILES
20
19
18
17
16
15
14
SANTA ANA INVESTIGATION

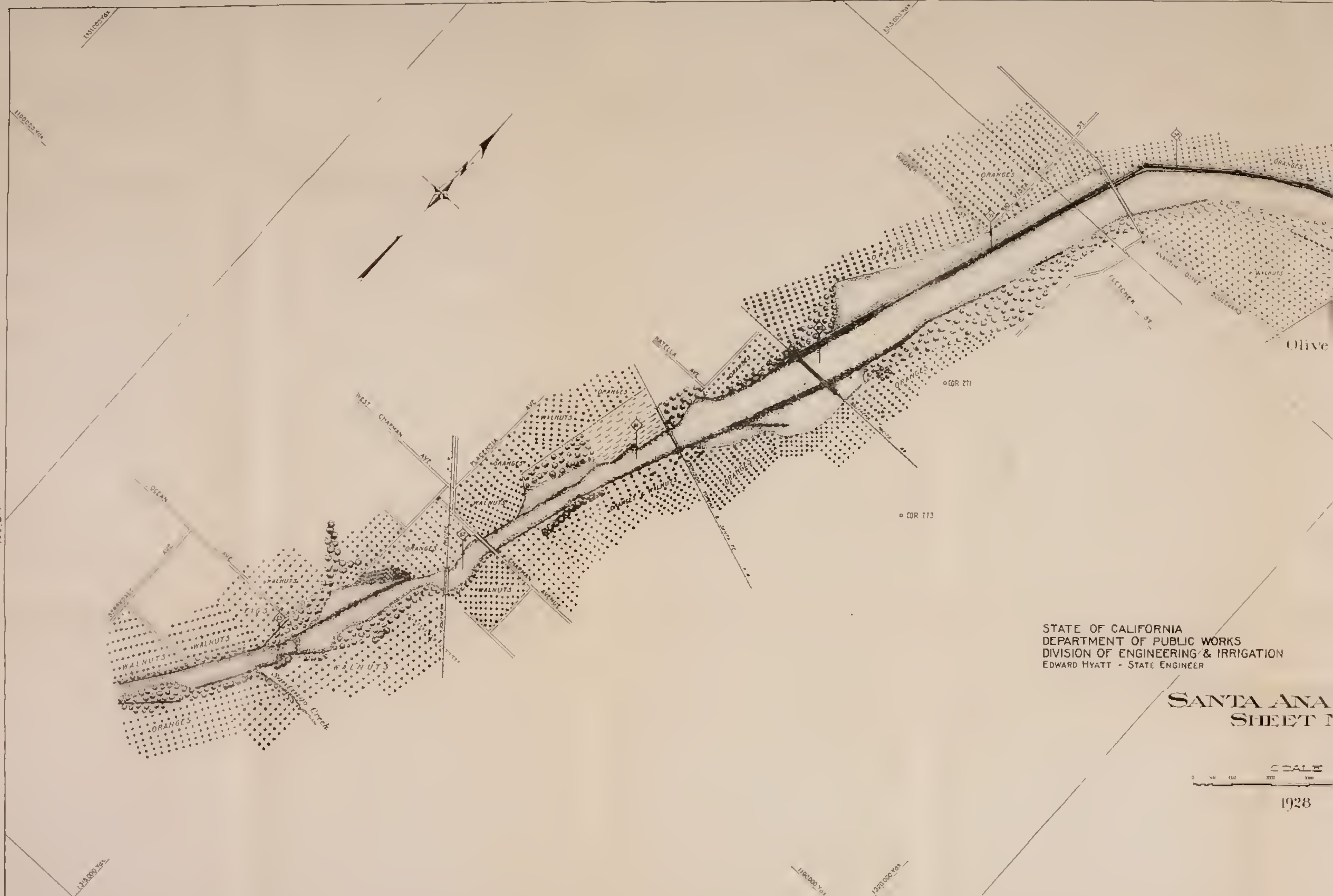

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING & IRRIGATION
EDWARD HYATT - STATE ENGINEER
SANTA ANA RIVE
SHEET Nº3
SCALE
1928
SAN
Norco
Gun Club Reservoir
Santa
ARCHIBALD AVE
CHANDLER ST
SUMNER AVE
CITRUS ST
CLEVELAND AVE
ADAMS AVE
HAMNER AVE
AUBURNDALE ST
WATER ST
SECOND ST
RINCON ST
SMITH
Temescal Creek
ATCHISON TOPEKA & SANTA FE R R
117°35'
33°55'
ELEVATION IN FEET
1000
500
0
-500
AUBURNDALE ROAD BRIDGE
HAMNER AVE BRIDGE
PEDLEY POWER HOUSE (Abandoned)
RECENT ALLUVIUM
OLD ALLUVIUM
GRANITE
38
37
36
35
34
33
DISTANCE I
63685



MAP 1
SHEET 3 OF 6 SHEETS
Rectangular Coordinates are indicated in margin for 5000 yard squares parallel and at right angles to the 121° Meridian (Army Grid System, Zone G, see U S C & G Survey Special Publication N° 59 Dept of Commerce 1919)
Latitude & Longitude lines shown are on North American Datum To plat corresponding lines of U S Geological Survey Maps before 1924, scale approximately 650 feet north and 380 feet east
Topography by Water Resources Investigation & D L Seal Topographer Santa Ana Investigation
Zero of Mile Posts is the U S G S gaging station near Mentone
Stream conditions represent average summer conditions and culture as of July 1928
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
RIVER
N°3
UNION
PACIFIC
Reservoir
PIPE FLUME
PEDLEY BRIDGE
U P R R BRIDGE
RECENT ALLUVIUM
NT ALLUVIUM
OLD ALLUVIUM
GRANITE
- NOTE -
Position of Bed Rock Deduced from General Geologic Information in Area
1000
500
0
-500
ELEVATION IN FEET
E IN MILES
32
31
30
29
28
27
SANTA ANA INVESTIGATION


Rectangular Coordinates are indicated in margin for 5000 yard squares parallel and at right angles to the 121° Meridian (Army Grid System, Zone G, see U.S.C.&G. Survey Special Publication Nº 59, Dept of Commerce, 1919)
Latitude & Longitude lines are on North American Datum. To plot corresponding lines of U.S. Geological Survey Maps before 1924, scale approximately 650 feet North & 380 feet east
Topography by Water Resources Investigation & Orange County Flood Control
the U.S.G.S. gaging station near Mentone
represent average summer conditions and culture as of July 1928
Esperanza
S.A.V.I. Well Nº 1
Oil Well Site
Test Drilling
Test Drilling
Sulphur Slide Point
Sycamore Camp
Santa
Ana
Scully Point
U.S.G.S. Gage
Green River Camp
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING & IRRIGATION
EDWARD HYATT - STATE ENGINEER
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
SANTA ANA RIVER
SHEET Nº4
SCALE
1928
ELEVATION IN FEET
1000
500
0
-500
Oil Well Dam Site (Test Drilling)
Sulphur Slide (Test Drilling)
SHALE AND SANDSTONE
51
50
49
48
47
46
45
DISTANCE

MAP 1
SHEET 4 OF 6 SHEETS
Store
Prado
Temescal Wash
River
Ana
Scully Point
U.S.G.S. Gage
Green River Camp
Prado Site Test Drilling
Riverbank Camp
Chester Site Test Drilling
Chester Dam Site (Test Drilling)
SANTA FE R.R.
Prado Dam Site (Test Drilling)
CHINO ROAD BRIDGE
RECENT ALLUVIUM
OLD ALLUVIUM
SHALE SANDSTONE AND CONGLOMERATE
SHALE AND SANDSTONE
1000
500
0
-500
ELEVATION IN FEET
-NOTE-
Position of Bed Rock Deduced from General Geologic Information in Area
SANTA ANA INVESTIGATION
46
45
44
43
42
41
40
39
DISTANCE IN MILES

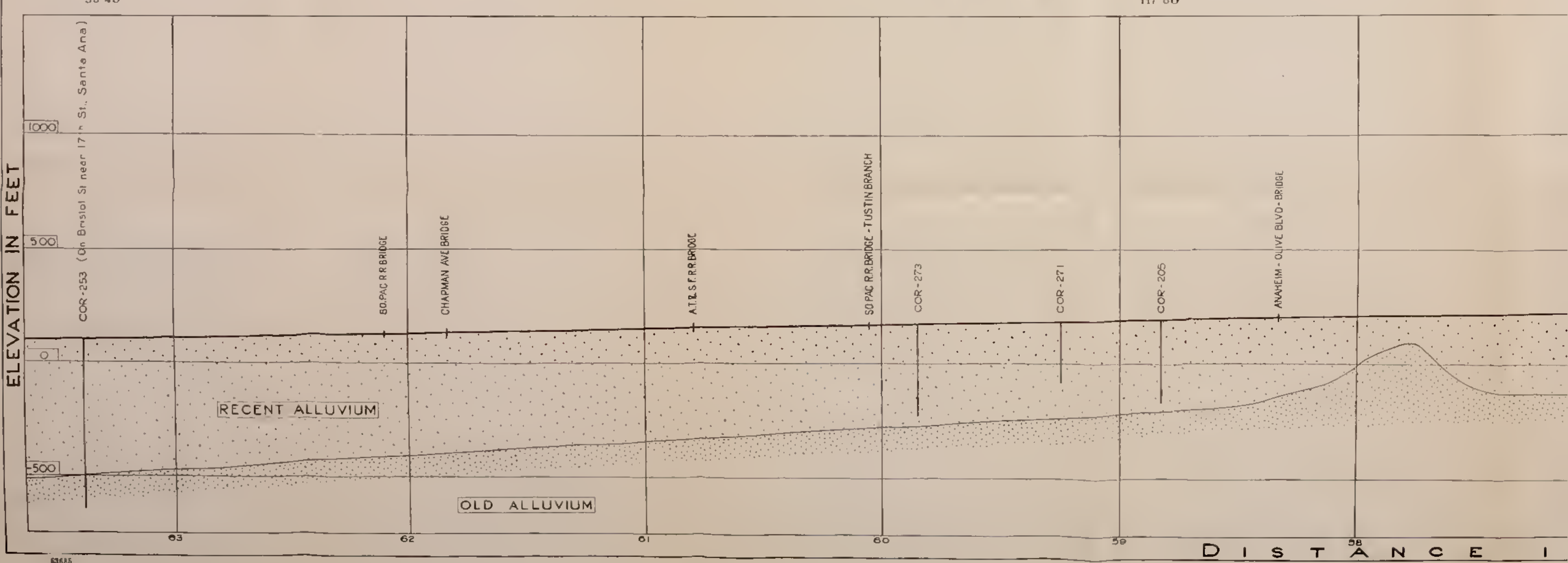


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING & IRRIGATION
EDWARD HYATT - STATE ENGINEER

SANTA ANA
SHEET N

SCALE

1928



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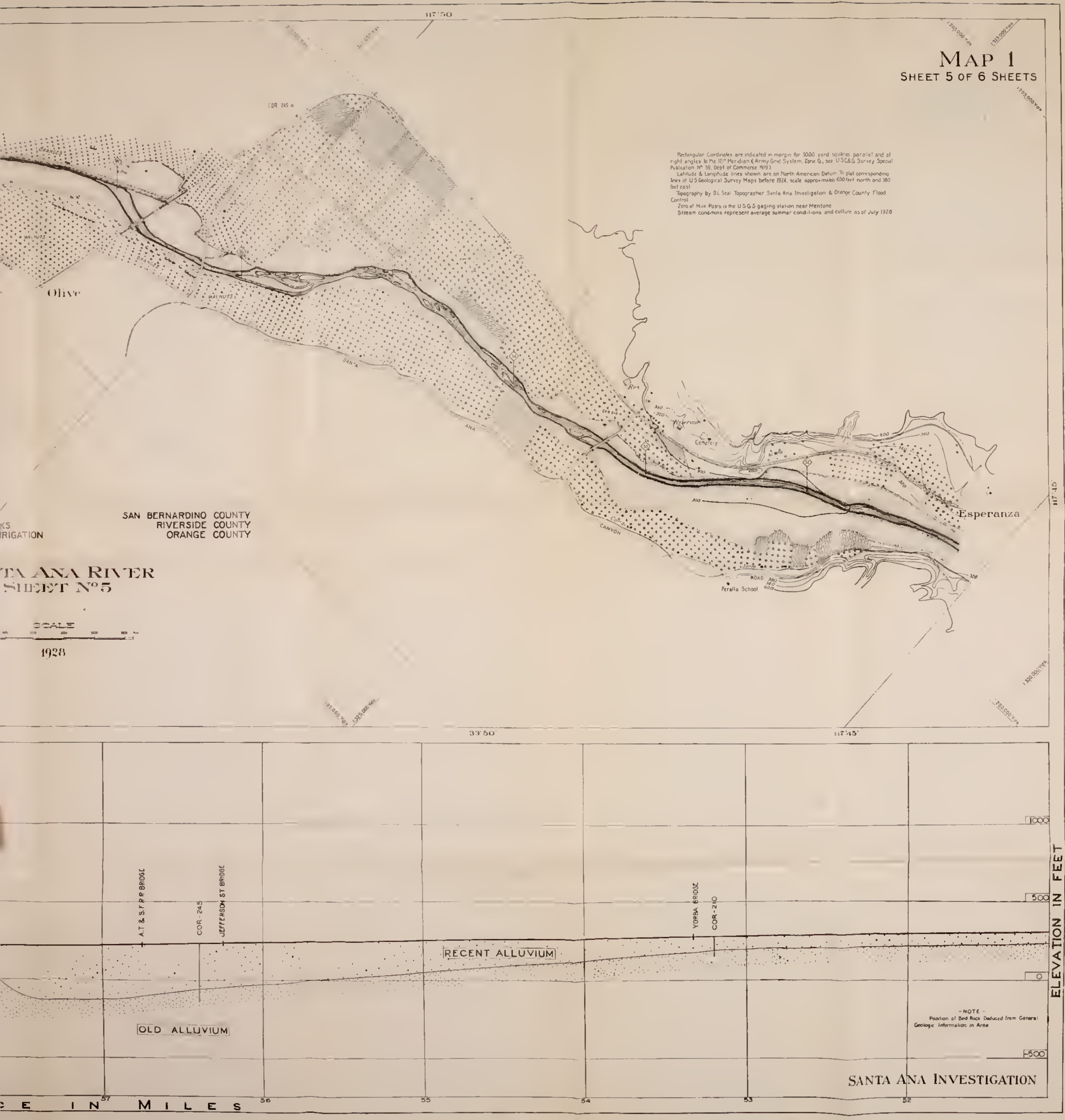
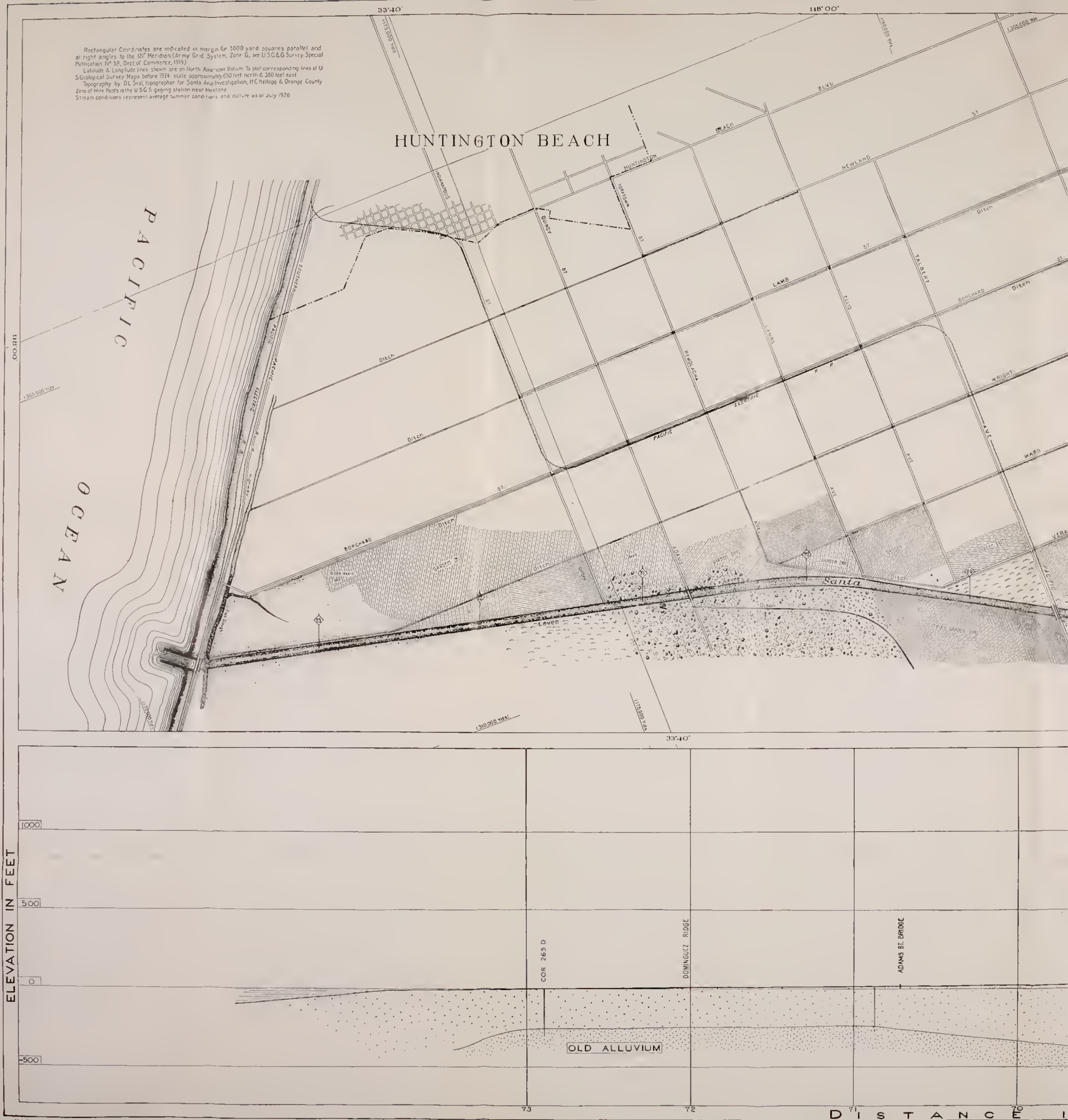
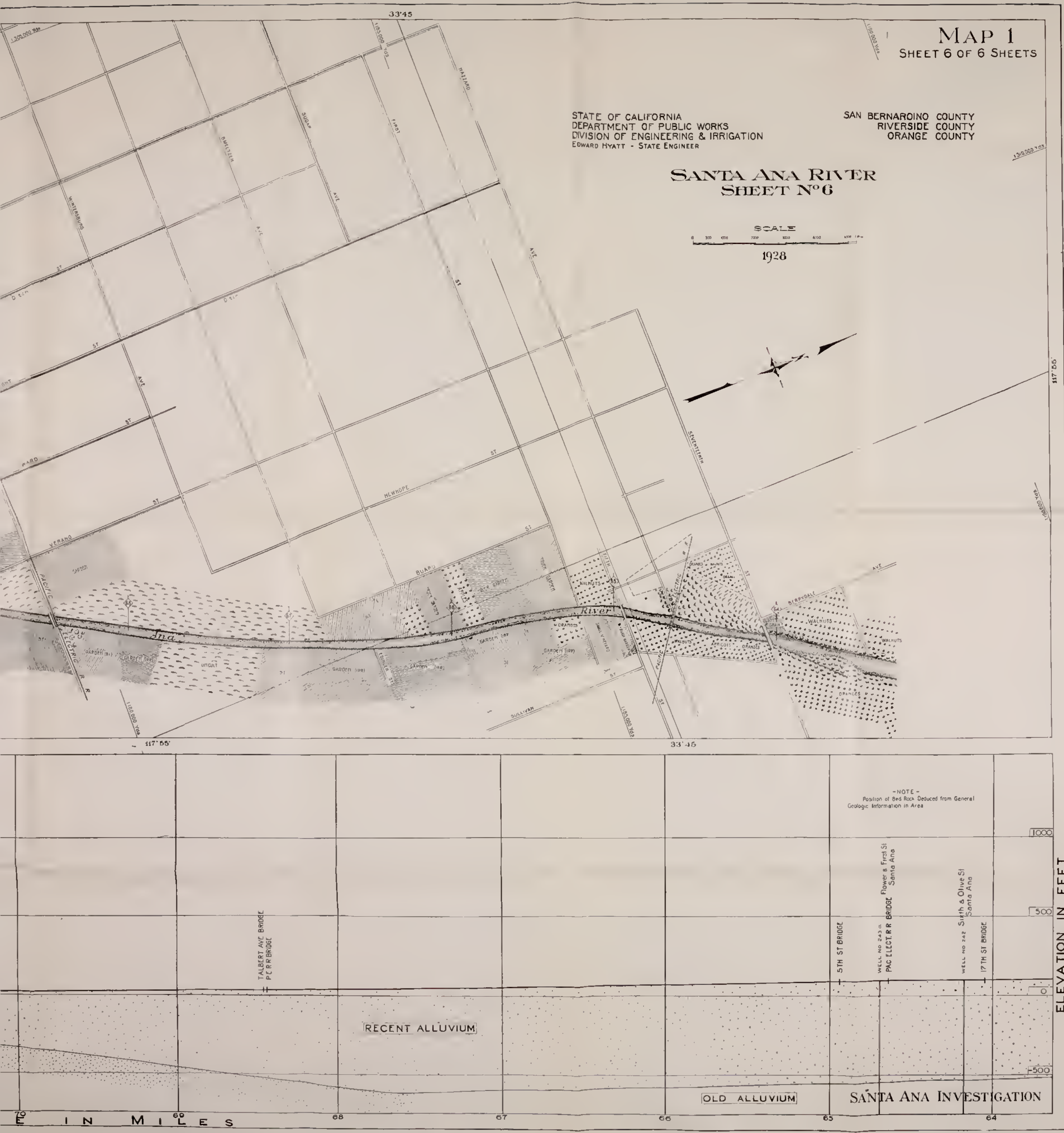

MAP 1
SHEET 5 OF 6 SHEETS
Rectangular Coordinates are indicated in margin for 5000 yard squares parallel and at right angles to the 121° Meridian (Army Grid System, Zone G., see U.S.C.&G. Survey Special Publication Nº 59, Dept of Commerce 1919)
Latitude & Longitude lines shown are on North American Datum. To plot corresponding lines of U.S. Geological Survey Maps before 1924, scale approximately 650 feet north and 380 feet east
Topography by D.L. Seal, Topographer, Santa Ana Investigation & Orange County Flood Control
Zero of Mile Posts is the U.S.G.S. gaging station near Mentone
Stream conditions represent average summer conditions and culture as of July 1928
117°50'
Olive
Esperanza
Peralta School
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
TA ANA RIVER
SHEET Nº5
SCALE
1928
33°50'
117°45'
A.T. & S.F. R.R. BRIDGE
COR-245
JEFFERSON ST BRIDGE
YORBA BRIDGE
COR-210
RECENT ALLUVIUM
OLD ALLUVIUM
1000
500
0
-500
ELEVATION IN FEET
- NOTE -
Position of Bed Rock Deduced from General Geologic Information in Area
SANTA ANA INVESTIGATION
57
56
55
54
53
52
CE IN MILES

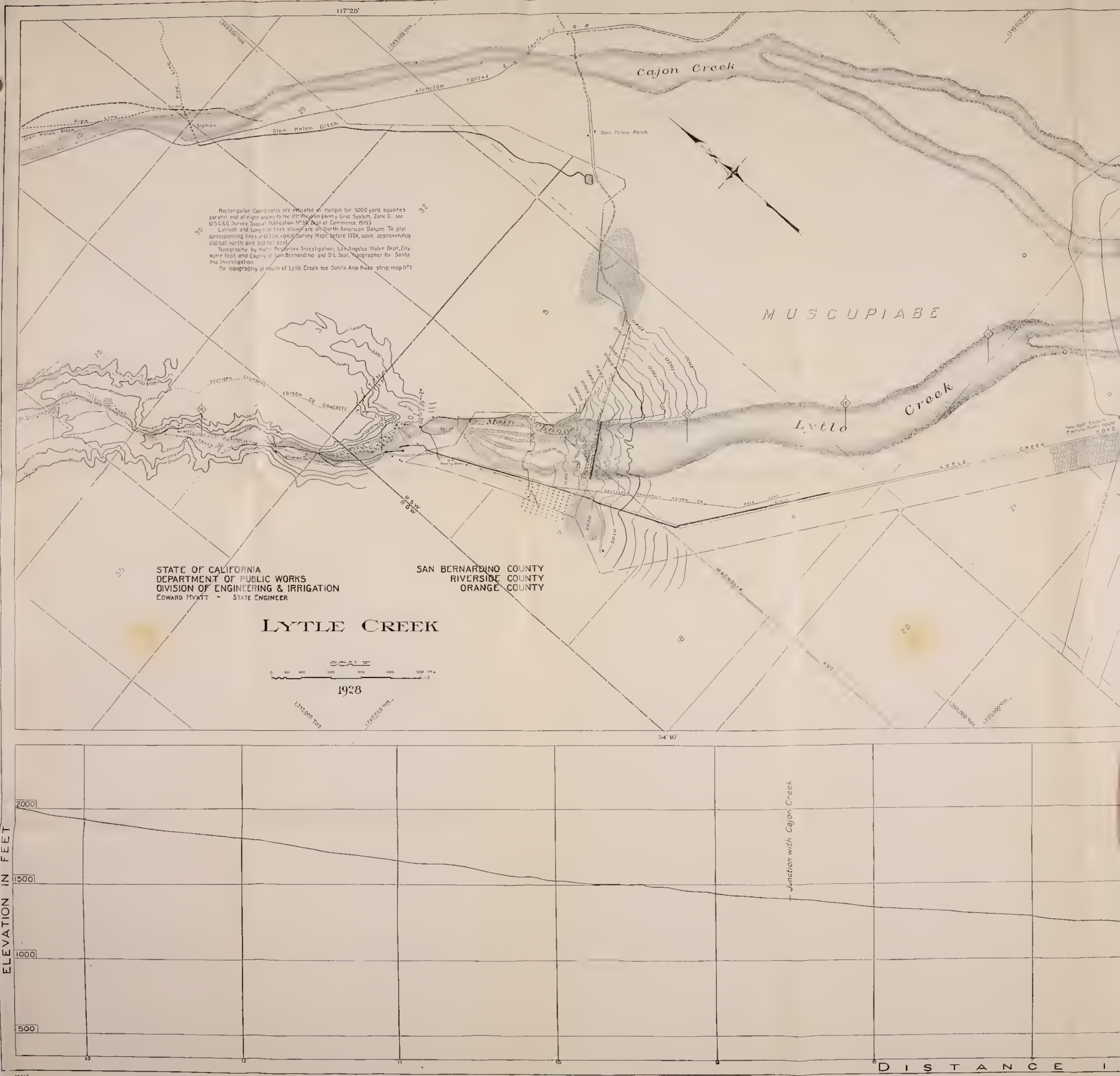


Rectangular Coordinates are indicated in margin for 3000 yard squares parallel and at right angles to the 121° Meridian (Army Grid System, Zone G, see U.S.C.&G. Survey Special Publication No 59, Dept of Commerce, 1919)
Latitude & Longitude lines shown are on North American Datum. To plot corresponding lines of U.S. Geological Survey Maps before 1924 scale approximately 650 feet north & 380 feet east
Topography by D.L. Seal, topographer for Santa Ana Investigation, H.C. Kellogg & Orange County
Zero of Mile Posts is the U.S.G.S. gaging station near Mentone
Stream conditions represent average summer conditions and culture as of July 1928
33°40'
118°00'
HUNTINGTON BEACH
PACIFIC
OCEAN
BLVD
BEACH
HUNTINGTON
NEWLAND
LAMB
ST
TALBERT
ELLIS
BORCHARD
WRIGHT
WARD
Ditch
Levee
Santa
QUINCY
PACIFIC ELECTRIC
ELEVATION IN FEET
1000
500
0
-500
COR 265 D
DOMINGUEZ RIDGE
ADAMS ST. BRIDGE
OLD ALLUVIUM
73
72
71
70
DISTANCE

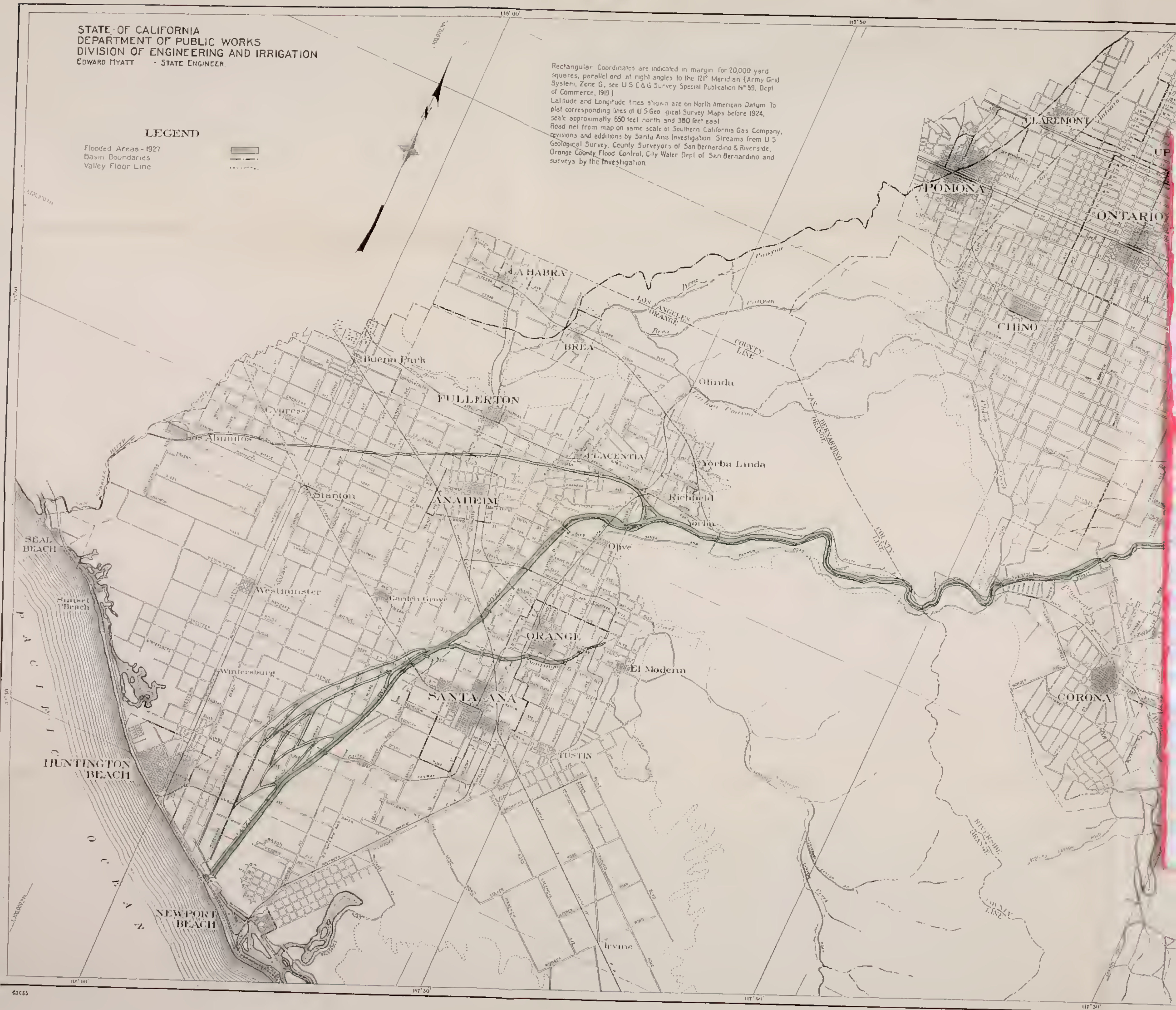
63685

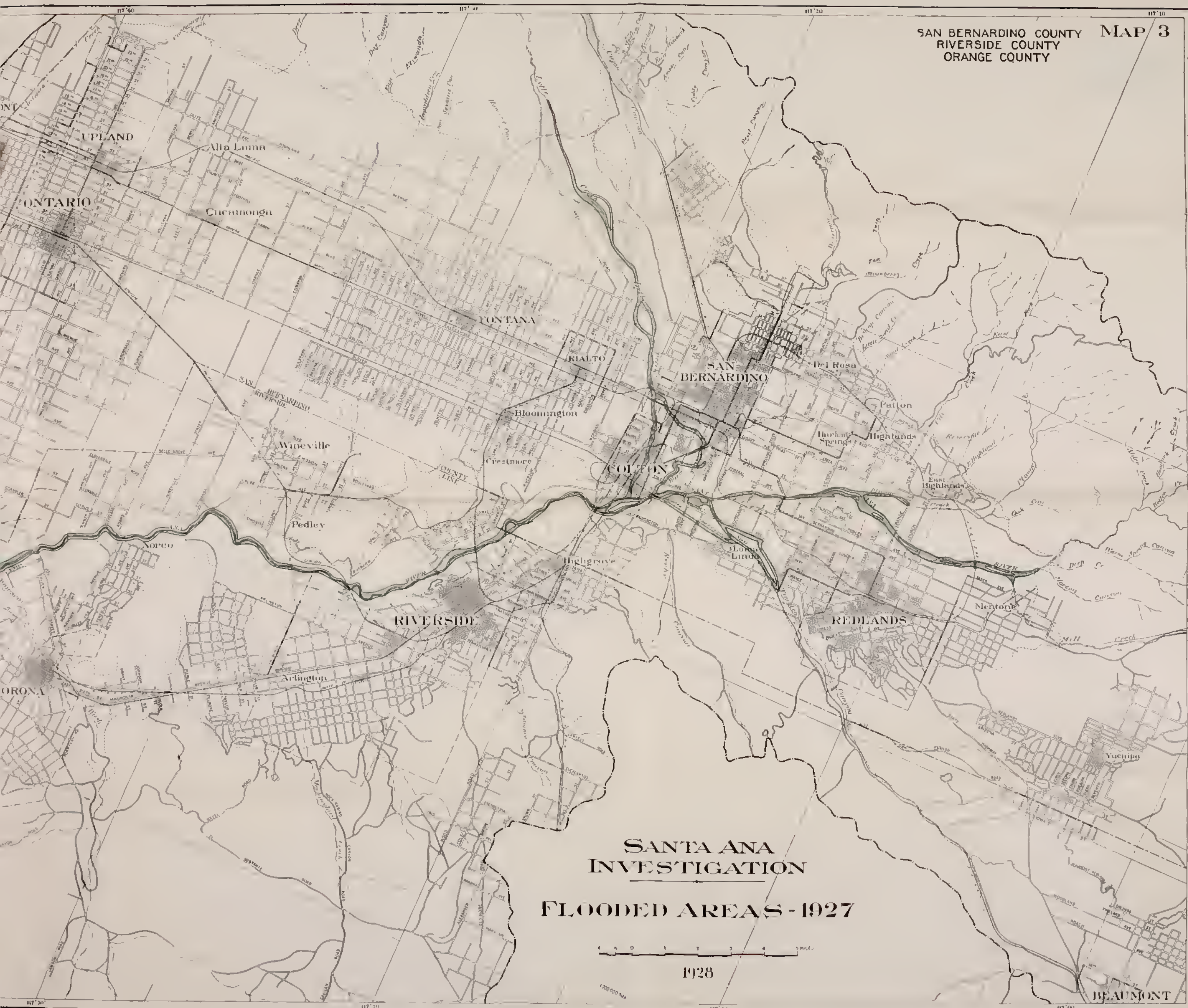


MAP 1
SHEET 6 OF 6 SHEETS
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING & IRRIGATION
EDWARD HYATT - STATE ENGINEER
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
SANTA ANA RIVER
SHEET N°6
SCALE
1928
33'45
117'55'
Ana
River
PACIFIC ELECTRIC R R
NEWHOPE ST
WARD ST
VERANO
SULLIVAN
SEVENTEENTH
WALNUTS
ORANGES
-NOTE-
Position of Bed Rock Deduced from General Geologic Information in Area
TALBERT AVE BRIDGE
P E R R BRIDGE
5TH ST BRIDGE
WELL NO 243
PAC ELECT R R BRIDGE
Flower & First St Santa Ana
WELL NO 242
Sixth & Olive St Santa Ana
17TH ST BRIDGE
1000
500
0
-500
ELEVATION IN FEET
RECENT ALLUVIUM
OLD ALLUVIUM
SANTA ANA INVESTIGATION
70
69
68
67
66
65
64
E IN MILES

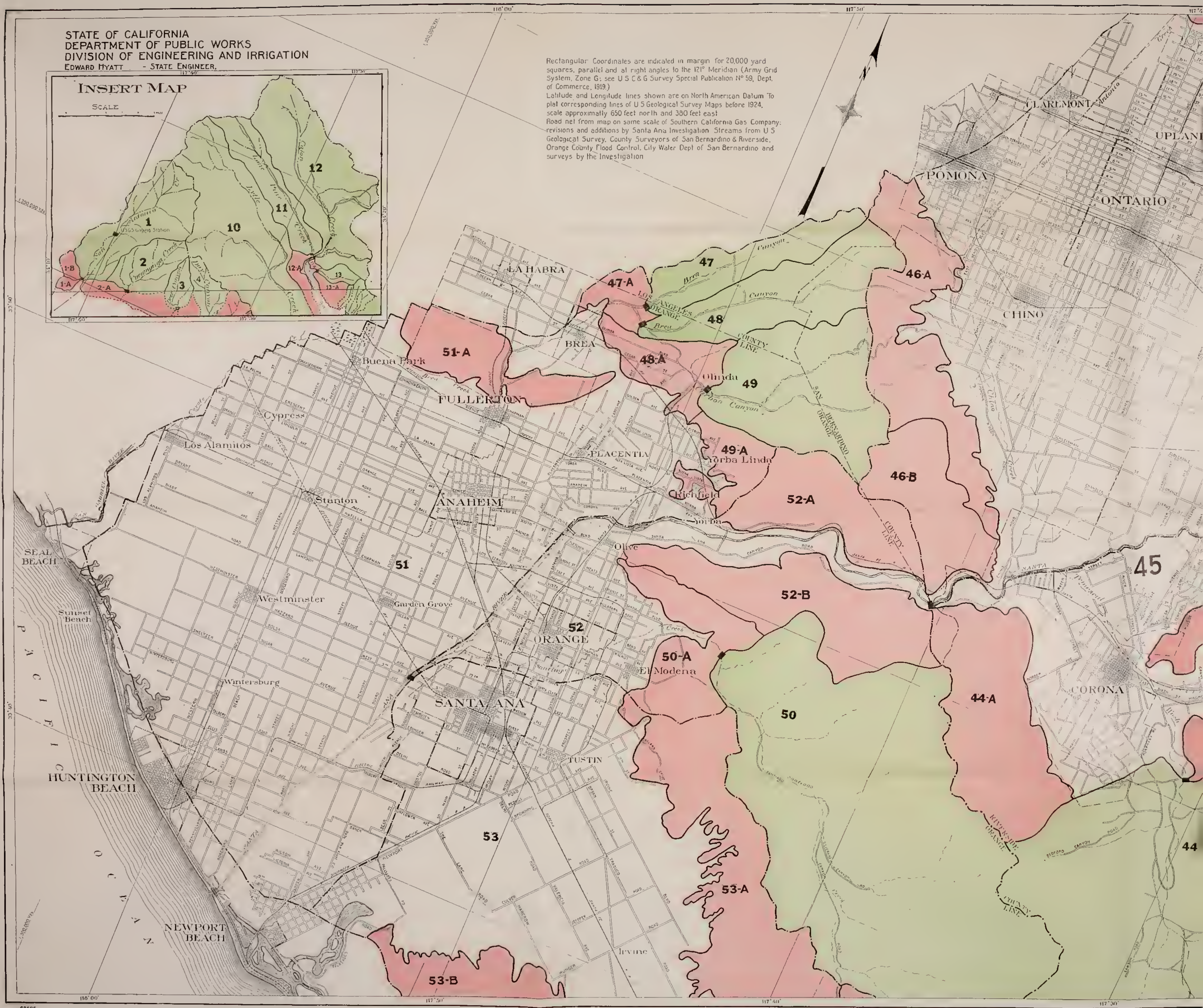

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING & IRRIGATION
EDWARD HYATT - STATE ENGINEER
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
LYTLE CREEK
SCALE
1928
Cajon Creek
Lytle Creek
MUSCUPIABE
Glen Helen Ditch
Glen Helen Ranch
Siphon
Pipe Line
ATCHISON TOPEKA & SANTA FE R R
EDISON CO CONCRETE
MAGNOLIA AVE
For topography at mouth of Lytle Creek see Santa Ana River strip map N°1
117°25'
34°10'
ELEVATION IN FEET
2000
1500
1000
500
Junction with Cajon Creek
DISTANCE

Map 2
34°10'
117°20'
117°25'
Cable Cañon Wash
SAN BERNARDINO
RIALTO
COLTON
Old Channel
Old Channel
A.T. & S.F. R.R. BRIDGE
Lytle Creek Mile 4.59 EQUATION
W. Br. Lytle Cr Mile 4.59
P.E.R.R. BRIDGE
A.T. & S.F. R.R. BRIDGE
COLTON AVE. BRIDGE
Junction with Warm Creek
West Branch Lytle Cr Mile 1.15 EQUATION
Santa Ana River – Mile 15
COLTON AVE BRIDGE
East Branch Lytle Cr Mile 0 EQUATION
Santa Ana River – Mile 14.10
2000
1500
1000
500
ELEVATION IN FEET
E IN MILES
SANTA ANA INVESTIGATION


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT - STATE ENGINEER
LEGEND
Flooded Areas - 1927
Basin Boundaries
Valley Floor Line
Rectangular Coordinates are indicated in margin for 20,000 yard squares, parallel and at right angles to the 121° Meridian (Army Grid System, Zone G, see U S C & G Survey Special Publication N° 59, Dept of Commerce, 1919)
Latitude and Longitude lines shown are on North American Datum To plat corresponding lines of U S Geological Survey Maps before 1924, scale approximatly 650 feet north and 380 feet east
Road net from map on same scale of Southern California Gas Company, revisions and additions by Santa Ana Investigation Streams from U S Geological Survey, County Surveyors of San Bernardino & Riverside, Orange County Flood Control, City Water Dept of San Bernardino and surveys by the Investigation
CLAREMONT
POMONA
ONTARIO
CHINO
LA HABRA
BREA
LOS ANGELES
ORANGE
COUNTY LINE
SAN BERNARDINO
ORANGE
Olinda
Buena Park
FULLERTON
Cypress
Los Alamitos
PLACENTIA
Yorba Linda
Richfield
Stanton
ANAHEIM
Olive
SEAL BEACH
Sunset Beach
Westminster
Garden Grove
ORANGE
El Modena
Wintersburg
SANTA ANA
TUSTIN
CORONA
HUNTINGTON BEACH
RIVERSIDE
ORANGE
COUNTY LINE
NEWPORT BEACH
Irvine
P A C I F I C O C E A N
118°00'
117°50'
117°40'
117°30'
63085



SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
MAP 3
UPLAND
Alta Loma
ONTARIO
Cucamonga
FONTANA
RIALTO
SAN BERNARDINO
Del Rosa
Patton
Highlands
Bloomington
Wineville
Crestmore
COLTON
East Highlands
Pedley
Norco
Highgrove
Loma Linda
Mentone
RIVERSIDE
REDLANDS
Arlington
ORONA
Yucaipa
BEAUMONT
SANTA ANA
INVESTIGATION
FLOODED AREAS - 1927
1928


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT - STATE ENGINEER.
INSERT MAP
SCALE
Rectangular Coordinates are indicated in margin for 20,000 yard squares, parallel and at right angles to the 121° Meridian (Army Grid System, Zone G; see U S C & G Survey Special Publication N° 59, Dept. of Commerce, 1919.)
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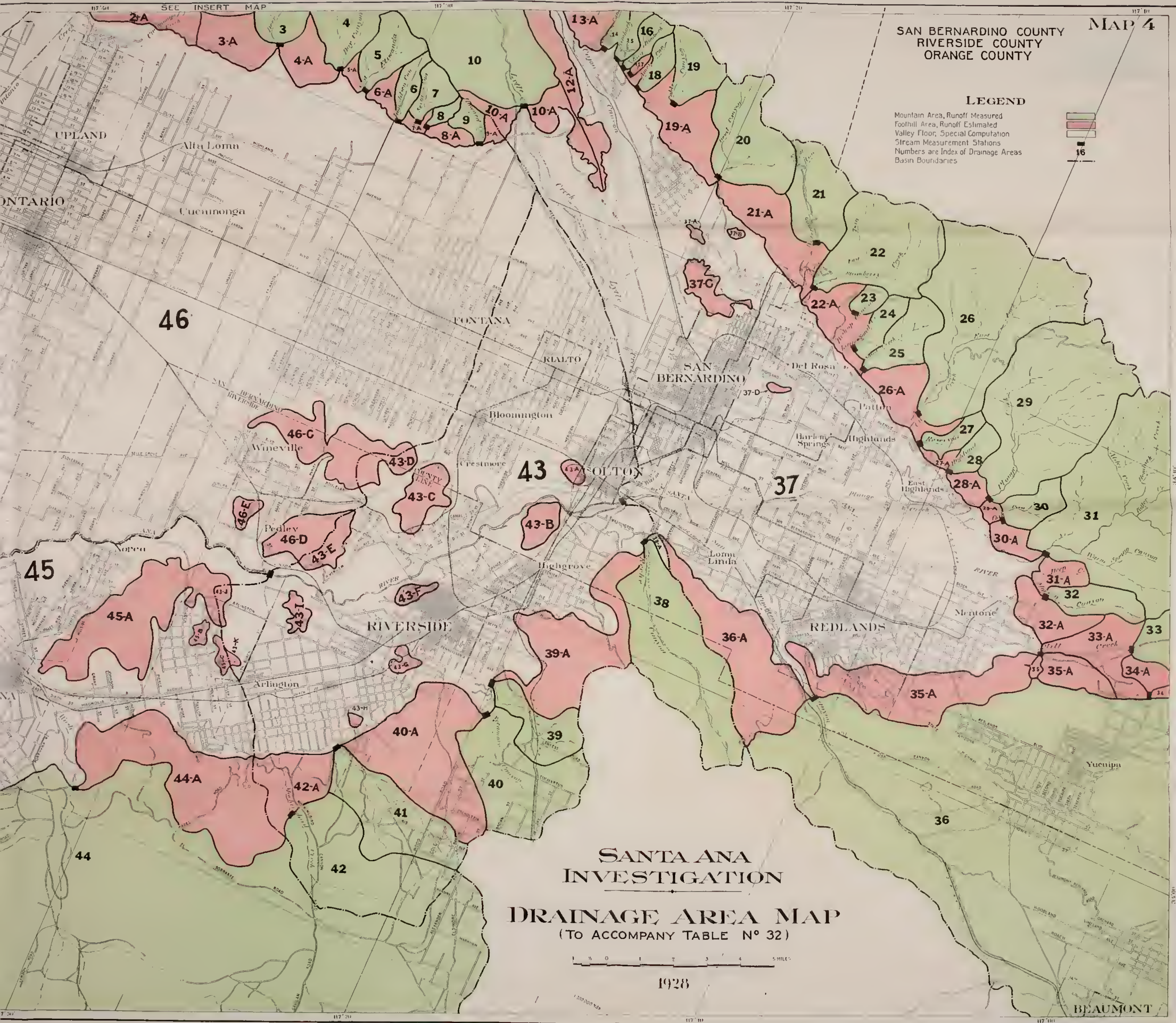
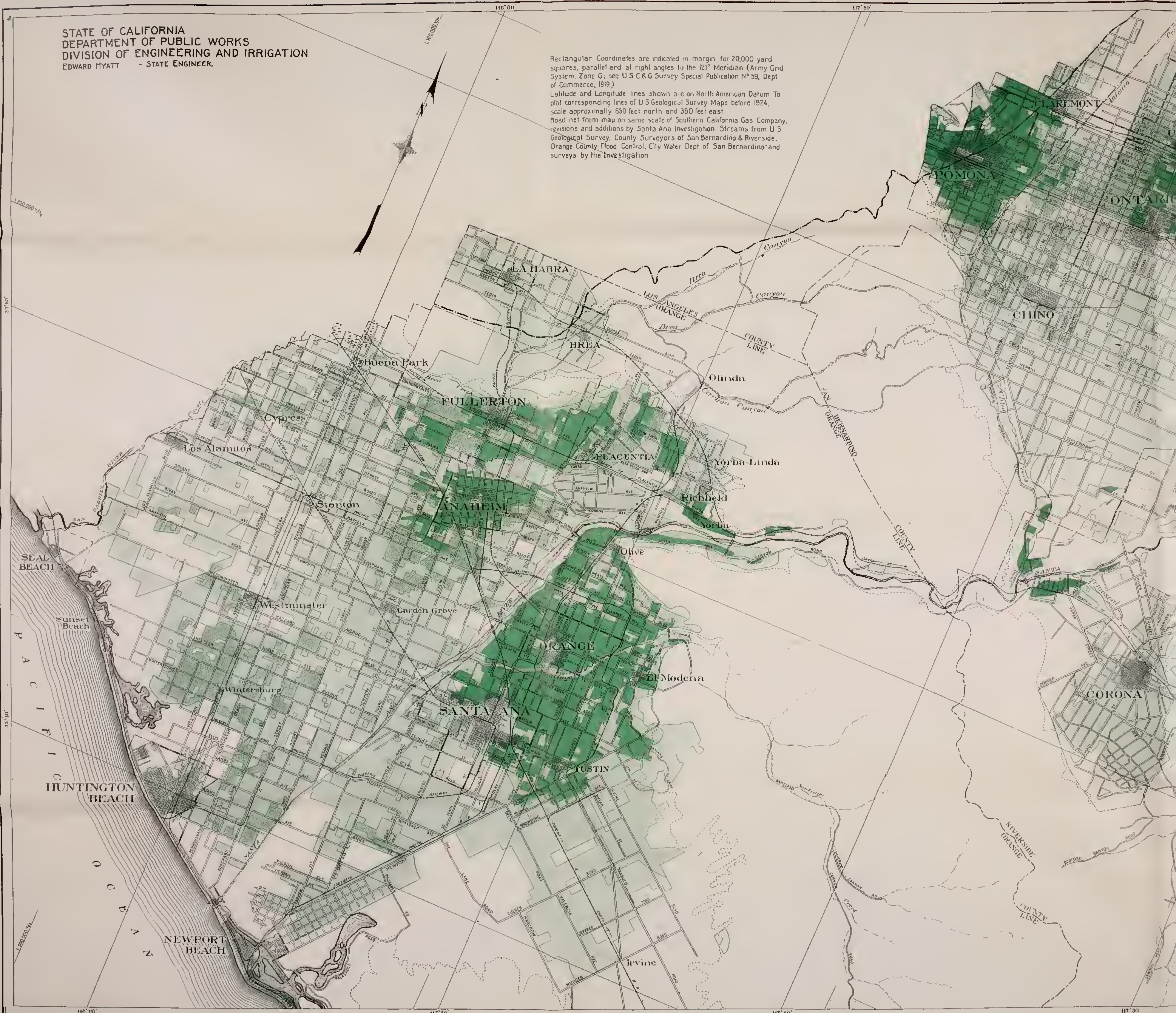
Road net from map on same scale of Southern California Gas Company; revisions and additions by Santa Ana Investigation Streams from U S Geological Survey, County Surveyors of San Bernardino & Riverside, Orange County Flood Control, City Water Dept of San Bernardino and surveys by the Investigation
CLAREMONT
UPLAND
POMONA
ONTARIO
CHINO
CORONA
LA HABRA
BREA
Buena Park
FULLERTON
Cypress
Los Alamitos
PLACENTIA
Yorba Linda
Richfield
Yorba
Olinda
Stanton
ANAHEIM
Olive
SEAL BEACH
Westminster
Garden Grove
ORANGE
El Modena
Sunset Beach
Wintersburg
SANTA ANA
TUSTIN
HUNTINGTON BEACH
NEWPORT BEACH
Irvine
PACIFIC OCEAN
LOS ANGELES ORANGE COUNTY LINE
SAN BERNARDINO ORANGE COUNTY LINE
RIVERSIDE ORANGE
1
1-A
1-B
2
2-A
3
4
10
11
12
12-A
13
13-A
44
44-A
45
46-A
46-B
47
47-A
48
48-A
49
49-A
50
50-A
51
51-A
52
52-A
52-B
53
53-A
53-B
63685


SEE INSERT MAP
MAP 4
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
LEGEND
Mountain Area, Runoff Measured
Foothill Area, Runoff Estimated
Valley Floor, Special Computation
Stream Measurement Stations
Numbers are Index of Drainage Areas
Basin Boundaries
16
UPLAND
Alta Loma
ONTARIO
Cucamonga
FONTANA
RIALTO
SAN BERNARDINO
Del Rosa
Patton
Bloomington
Wineville
Crestmore
COLTON
Harlem Springs
Highlands
East Highlands
Pedley
Norco
Highgrove
Loma Linda
RIVERSIDE
REDLANDS
Mentone
Arlington
Yucaipa
BEAUMONT
2-A
3
3-A
4
4-A
5
6
6-A
7
8
8-A
9
10
10-A
12-A
13-A
16
18
19
19-A
20
21
21-A
22
22-A
23
24
25
26
26-A
27
28
28-A
29
30
30-A
31
31-A
32
32-A
33
33-A
34-A
35-A
36
36-A
37
37-C
37-D
38
39
39-A
40
40-A
41
42
42-A
43
43-B
43-C
43-D
43-E
43-F
43-H
44
44-A
45
45-A
46
46-C
46-D
46-E
SANTA ANA INVESTIGATION
DRAINAGE AREA MAP
(TO ACCOMPANY TABLE N° 32)
1928


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT - STATE ENGINEER.
Rectangular Coordinates are indicated in margin for 20,000 yard squares, parallel and at right angles to the 121° Meridian (Army Grid System, Zone G; see U S C & G Survey Special Publication Nº 59, Dept of Commerce, 1919.)
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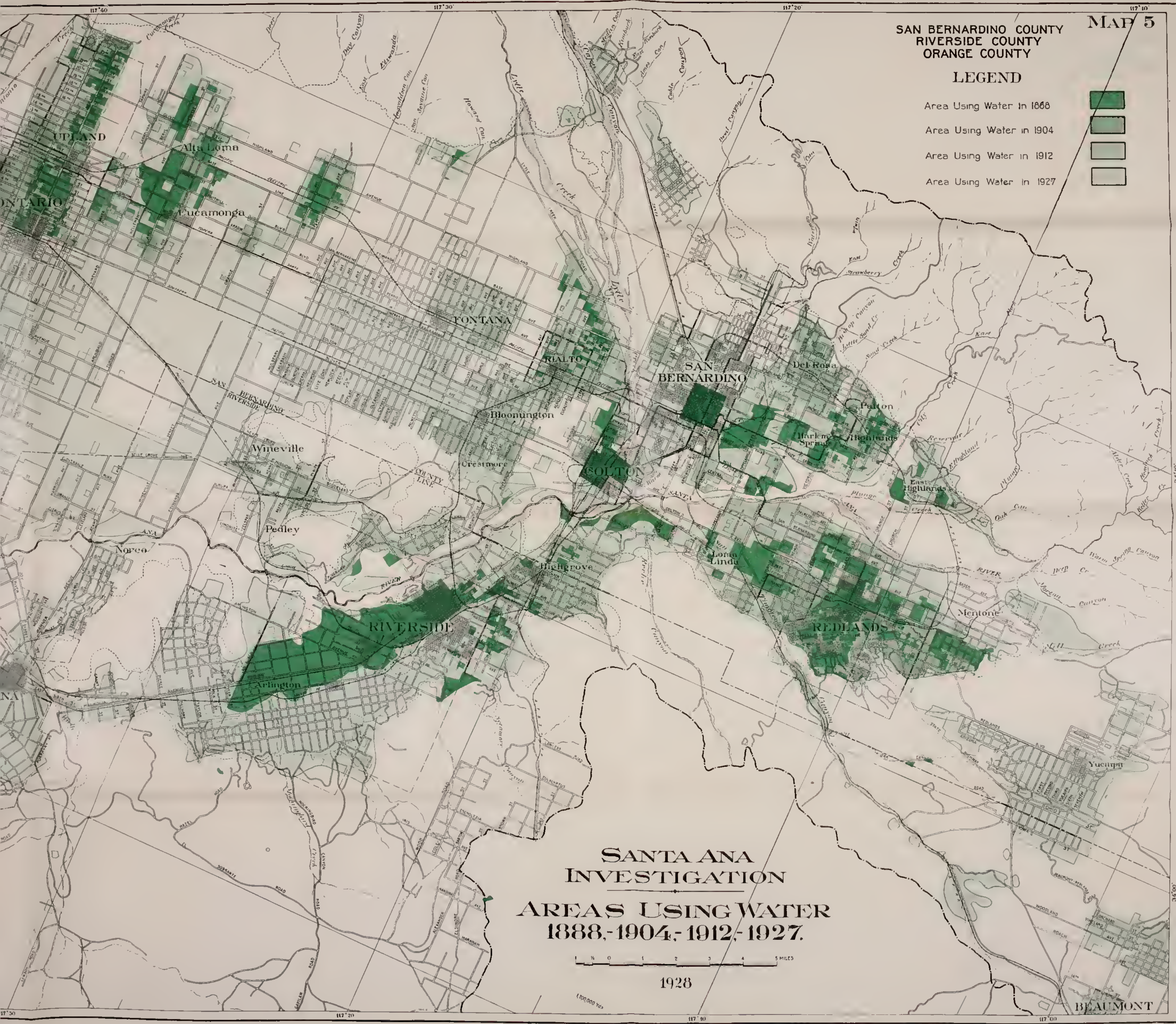
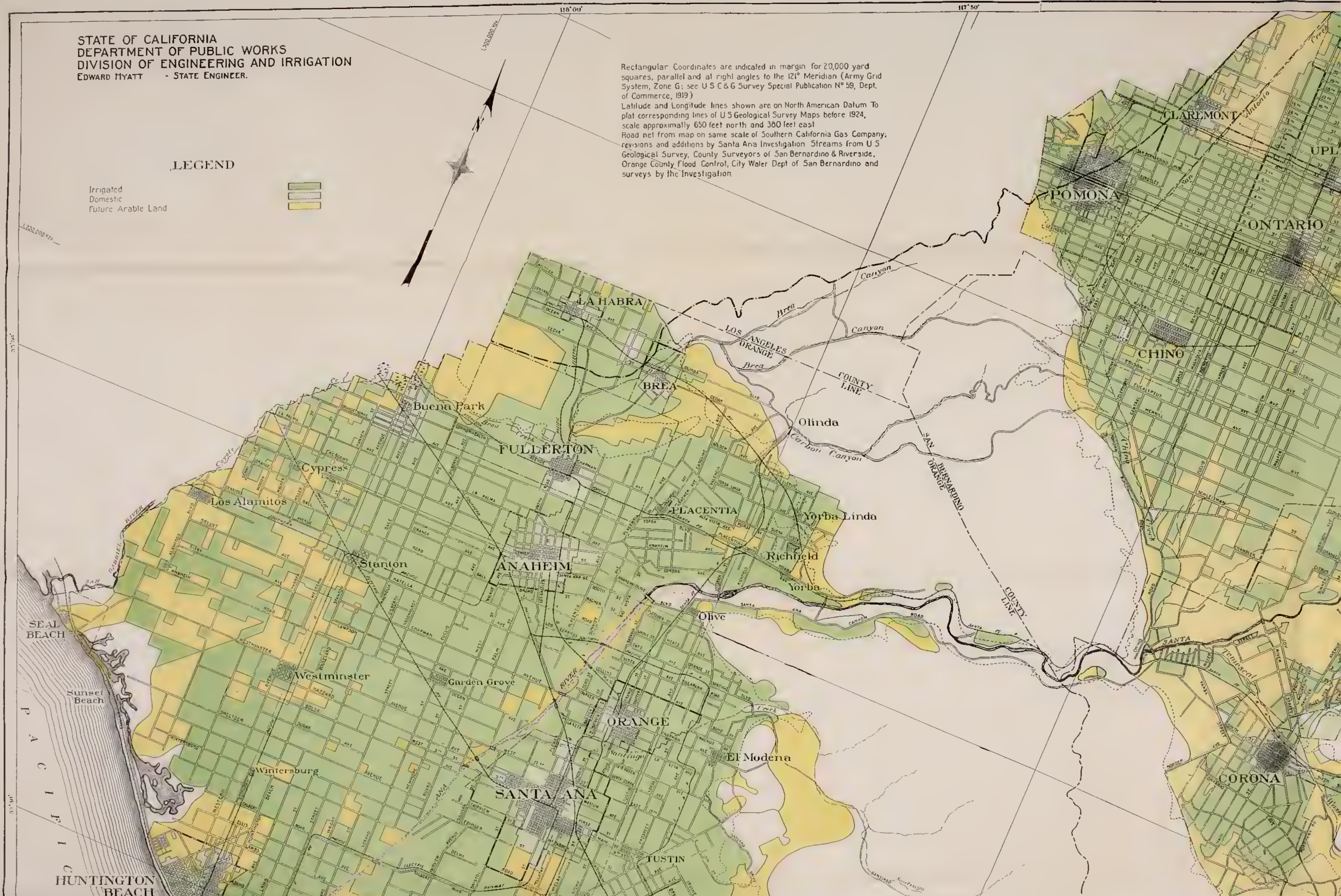
Road net from map on same scale of Southern California Gas Company, revisions and additions by Santa Ana Investigation Streams from U S Geological Survey, County Surveyors of San Bernardino & Riverside, Orange County Flood Control, City Water Dept of San Bernardino and surveys by the Investigation
118°00'
117°30'
118°10'
117°50'
117°40'
CLAREMONT
POMONA
ONTARIO
CHINO
LA HABRA
BREA
LOS ANGELES
ORANGE
COUNTY LINE
SAN BERNARDINO
ORANGE
COUNTY LINE
Olinda
Carbon Canyon
Brea Canyon
Buena Park
FULLERTON
Cypress
Los Alamitos
PLACENTIA
Yorba Linda
Richfield
Yorba
Stanton
ANAHEIM
Olive
SEAL BEACH
Westminster
Garden Grove
Sunset Beach
ORANGE
El Modena
CORONA
Wintersburg
SANTA ANA
TUSTIN
HUNTINGTON BEACH
RIVERSIDE
ORANGE
COUNTY LINE
P A C I F I C
O C E A N
NEWPORT BEACH
Irvine

63685


MAP 5
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
LEGEND
Area Using Water in 1888
Area Using Water in 1904
Area Using Water in 1912
Area Using Water in 1927
SANTA ANA
INVESTIGATION
AREAS USING WATER
1888,-1904,-1912,-1927.
1928
UPLAND
Alta Loma
ONTARIO
Cucamonga
FONTANA
RIALTO
SAN
BERNARDINO
Del Rosa
Patton
Harlem Springs
Highlands
Bloomington
Wineville
Crestmore
COLTON
East Highlands
Pedley
Norco
Highgrove
Loma Linda
RIVERSIDE
Arlington
REDLANDS
Mentone
Yucaipa
BEAUMONT
COUNTY LINE
SAN BERNARDINO RIVERSIDE
RIVER



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT - STATE ENGINEER.
Rectangular Coordinates are indicated in margin for 20,000 yard squares, parallel and at right angles to the 121° Meridian (Army Grid System, Zone G; see U S C & G Survey Special Publication N° 59, Dept. of Commerce, 1919)
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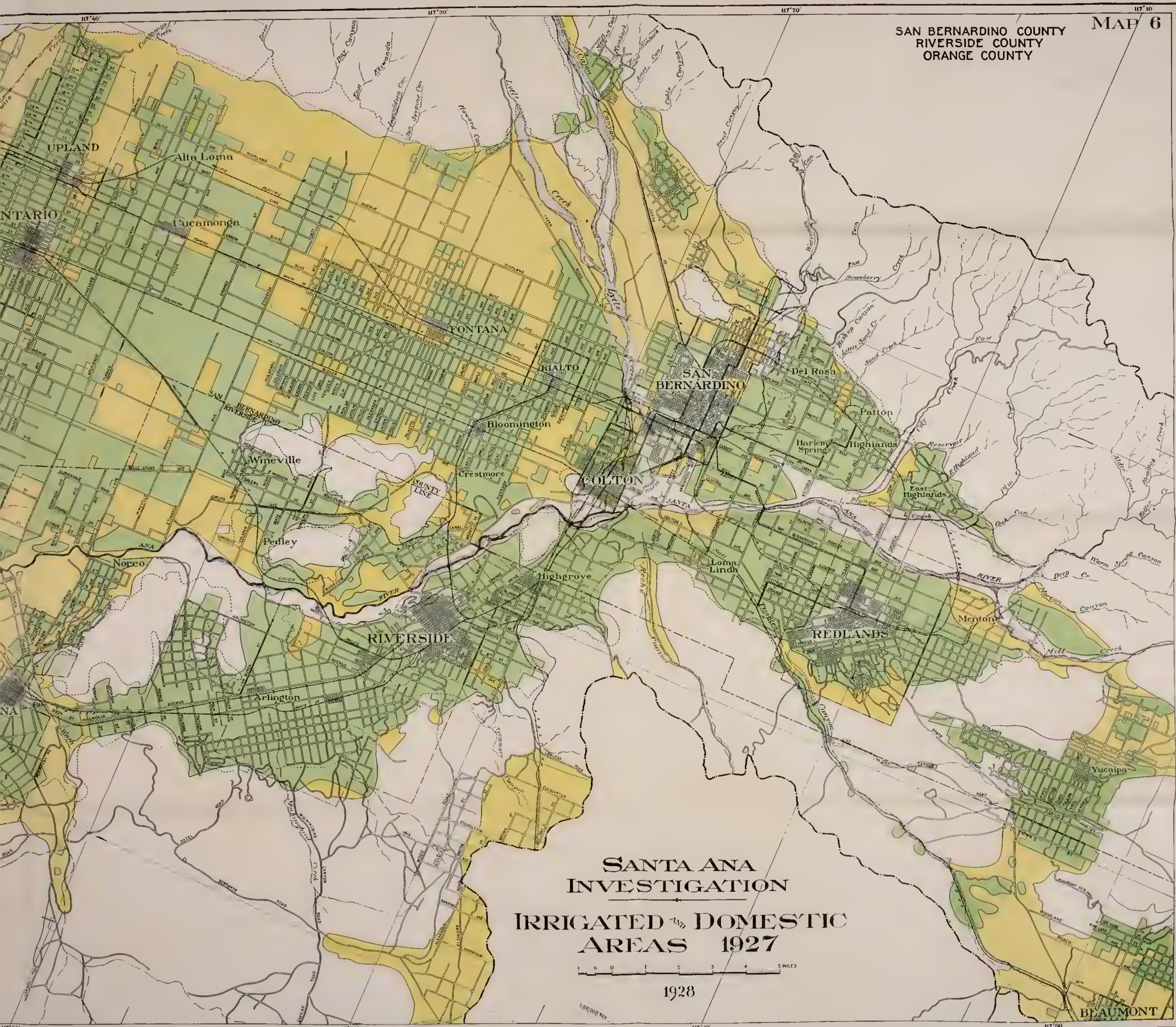
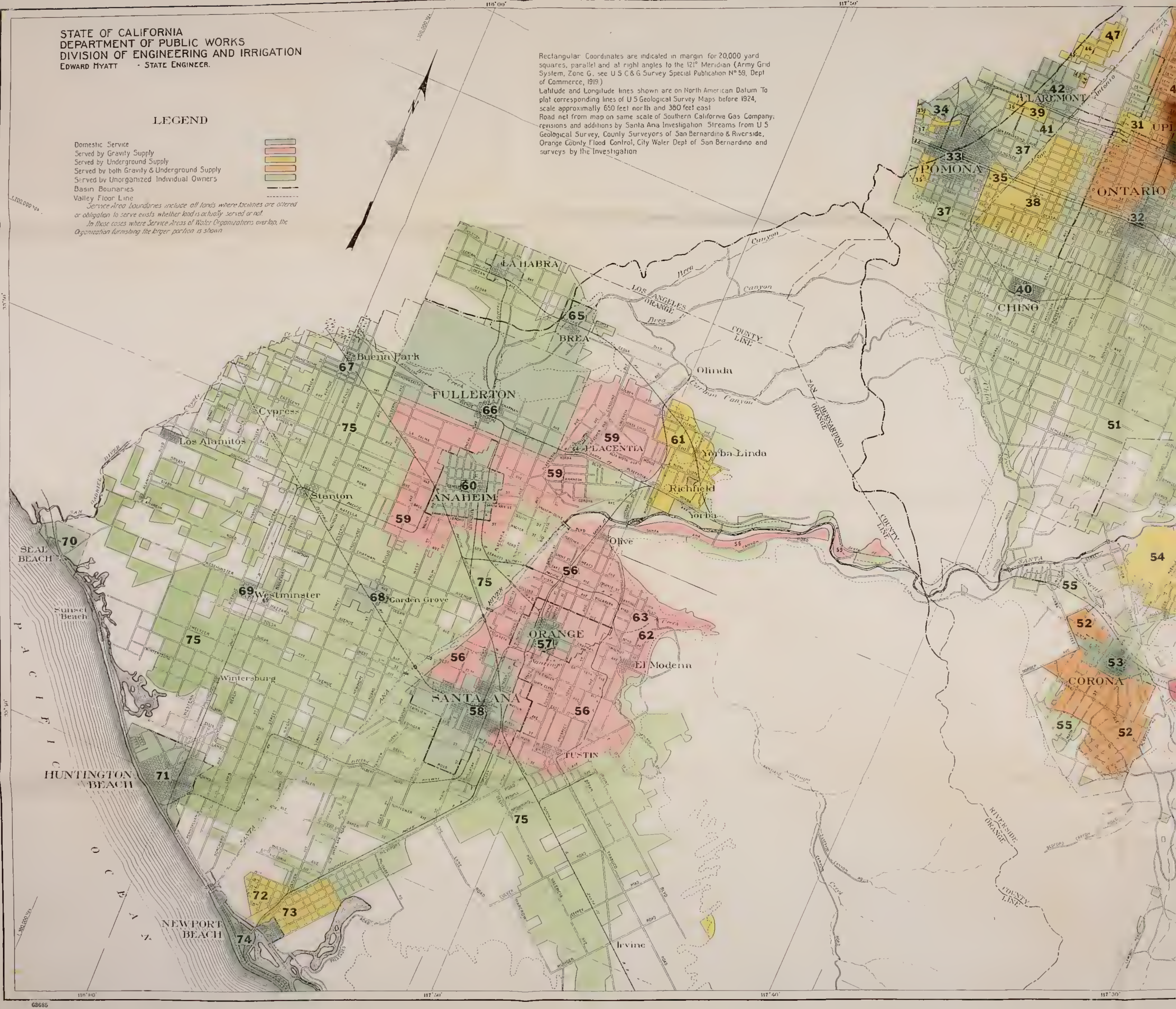
Road net from map on same scale of Southern California Gas Company; revisions and additions by Santa Ana Investigation Streams from U S Geological Survey, County Surveyors of San Bernardino & Riverside, Orange County Flood Control, City Water Dept of San Bernardino and surveys by the Investigation.
LEGEND
Irrigated
Domestic
Future Arable Land
118°00'
117°50'
117°40'
117°30'
CLAREMONT
POMONA
ONTARIO
CHINO
LA HABRA
BREA
LOS ANGELES
ORANGE
COUNTY LINE
SAN BERNARDINO
ORANGE
COUNTY LINE
Brea Canyon
Olinda
Carbon Canyon
Buena Park
FULLERTON
Cypress
Los Alamitos
PLACENTIA
Yorba Linda
Richfield
Yorba
Stanton
ANAHEIM
Olive
SEAL BEACH
Sunset Beach
Westminster
Garden Grove
ORANGE
El Modena
Wintersburg
SANTA ANA
TUSTIN
CORONA
HUNTINGTON BEACH
NEWPORT BEACH
Irvine
RIVERSIDE
ORANGE
COUNTY LINE
PACIFIC OCEAN
63685



MAP 6
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
SANTA ANA
INVESTIGATION
IRRIGATED AND DOMESTIC
AREAS 1927
1928
UPLAND
Alta Loma
ONTARIO
Cucamonga
FONTANA
RIALTO
SAN BERNARDINO
Del Rosa
Patton
Highlands
Harlem Springs
East Highlands
Bloomington
Wineville
Crestmore
COLTON
COUNTY LINE
Pedley
Norco
Highgrove
Loma Linda
RIVERSIDE
REDLANDS
Mentone
Arlington
Yucaipa
BEAUMONT
SANTA ANA RIVER
Lytle Creek
Mill Creek
117°40'
117°30'
117°20'
117°10'
117°00'
34°10'
34°00'



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT - STATE ENGINEER.
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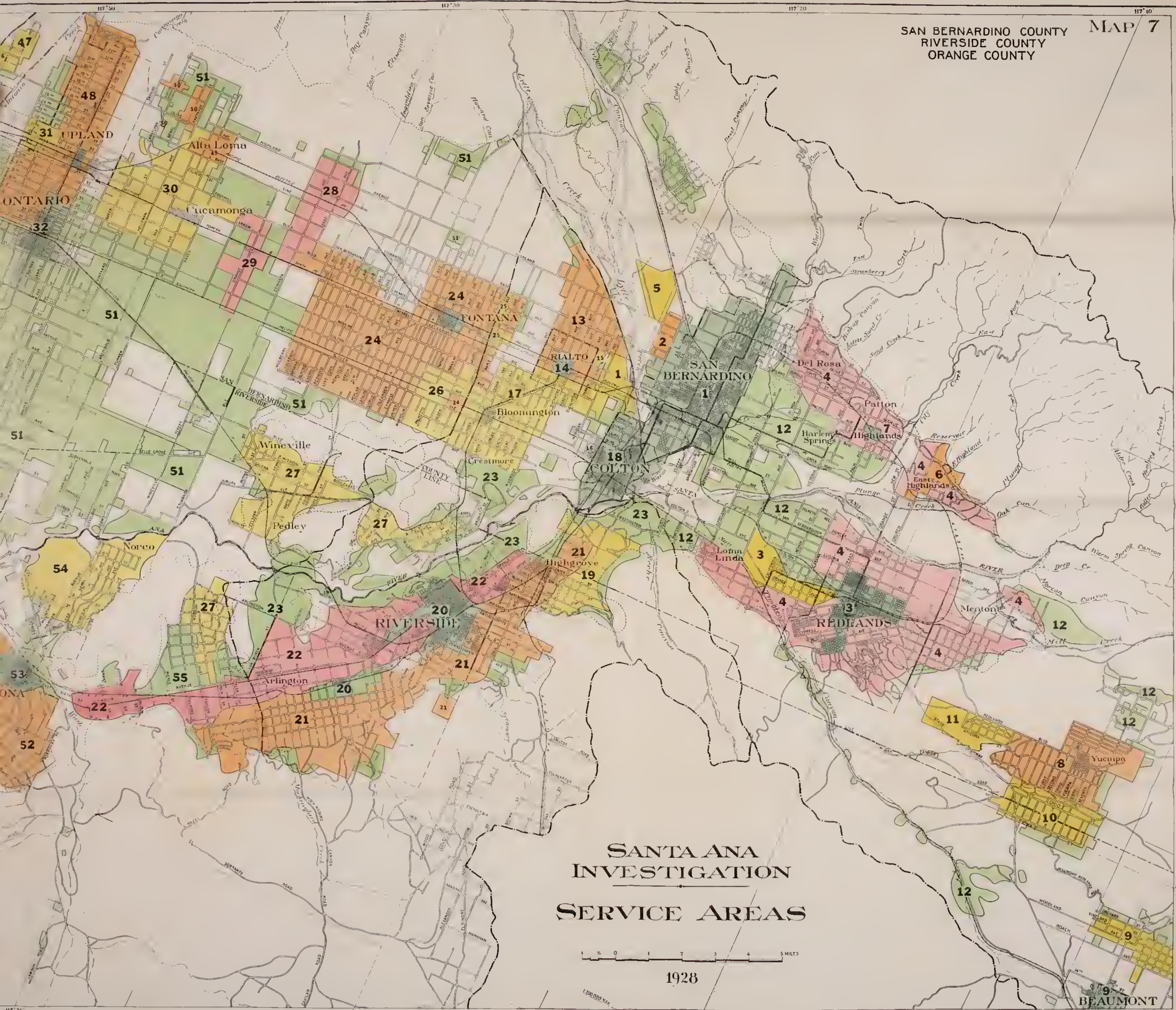
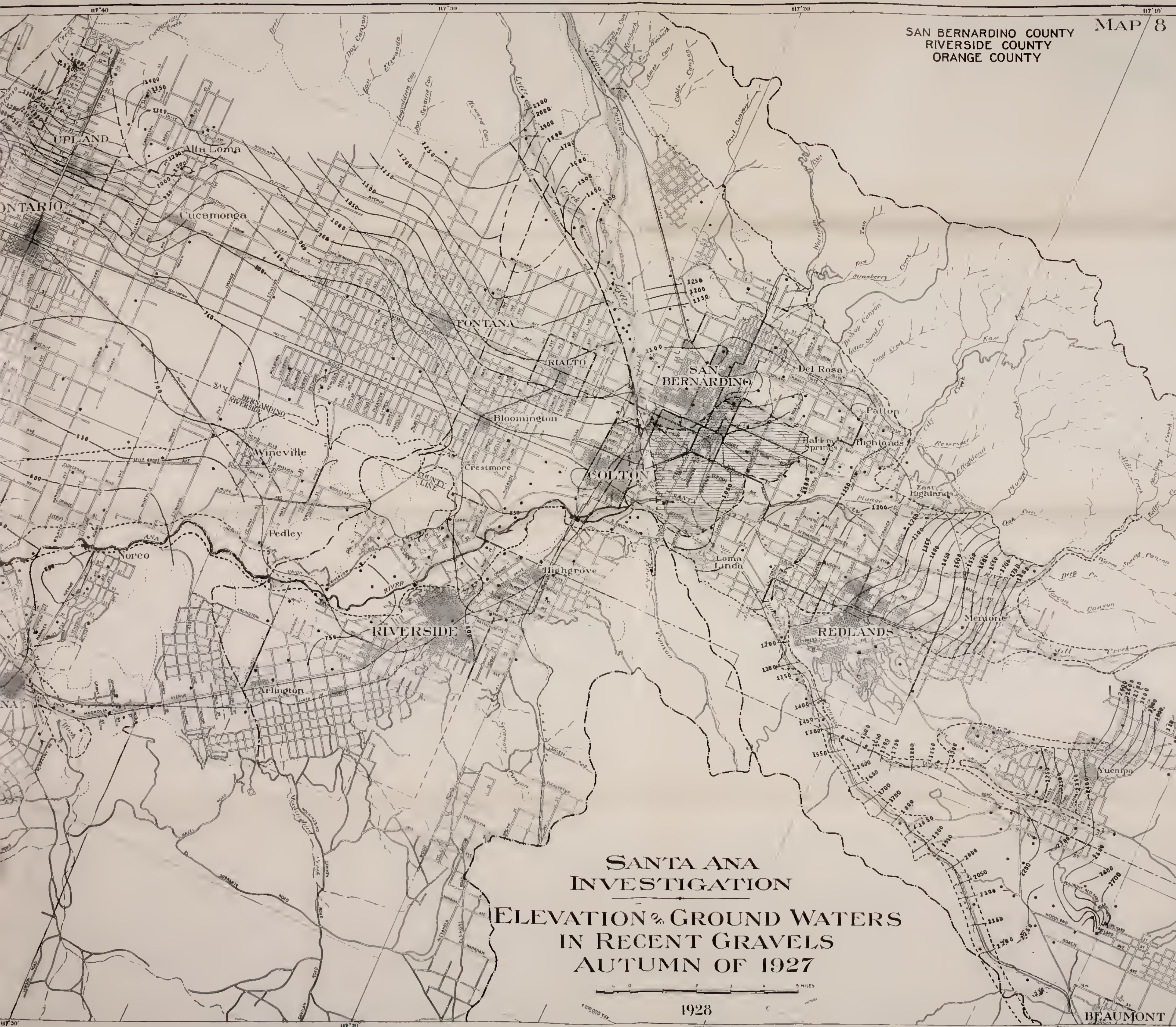
Road net from map on same scale of Southern California Gas Company; revisions and additions by Santa Ana Investigation. Streams from U S Geological Survey, County Surveyors of San Bernardino & Riverside, Orange County Flood Control, City Water Dept of San Bernardino and surveys by the Investigation
LEGEND
Domestic Service
Served by Gravity Supply
Served by Underground Supply
Served by both Gravity & Underground Supply
Served by Unorganized Individual Owners
Basin Bounaries
Valley Floor Line
Service Area boundaries include all lands where facilities are offered or obligation to serve exists whether land is actually served or not.
In those cases where Service Areas of Water Organizations overlap, the Organization furnishing the larger portion is shown
LA HABRA
BREA
LOS ANGELES
ORANGE
COUNTY LINE
SAN BERNARDINO
ORANGE
Olinda
Buena Park
FULLERTON
Cypress
Los Alamitos
PLACENTIA
Yorba Linda
Richfield
Yorba
ANAHEIM
Stanton
SEAL BEACH
Olive
Westminster
Garden Grove
Sunset Beach
ORANGE
El Modena
Wintersburg
SANTA ANA
TUSTIN
HUNTINGTON BEACH
NEWPORT BEACH
Irvine
PACIFIC OCEAN
POMONA
CLAREMONT
ONTARIO
CHINO
CORONA
RIVERSIDE
ORANGE
COUNTY LINE
47 42 34 39 31 41 33 37 35 38 37 32 40 51 65 67 66 75 59 61 64 59 60 59 70 56 75 69 68 63 62 57 75 56 58 56 71 75 72 73 74 54 55 52 53 55 52
63685

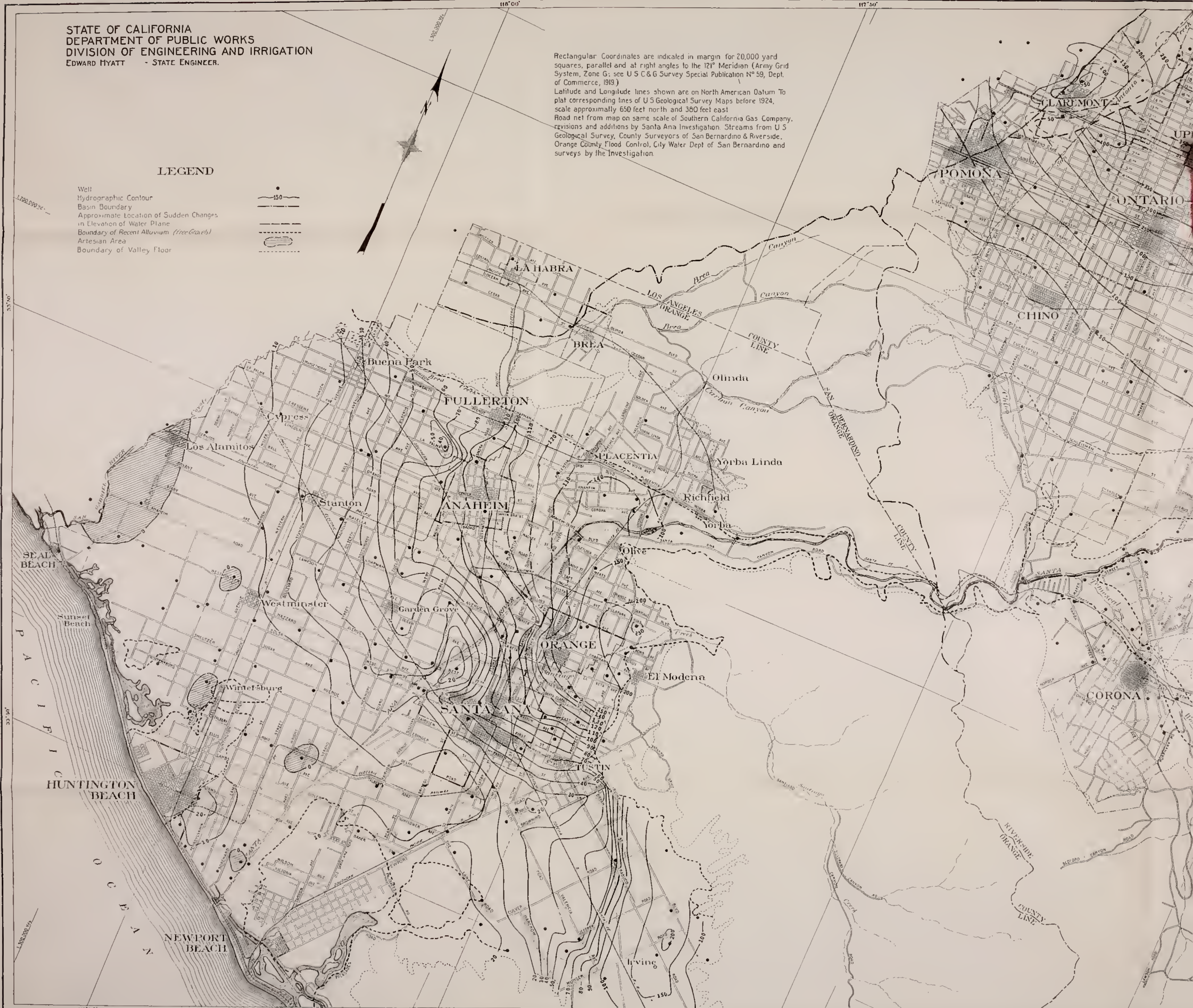


SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
MAP 7
SANTA ANA INVESTIGATION
SERVICE AREAS
1928
UPLAND
ONTARIO
Alta Loma
Cucamonga
FONTANA
RIALTO
SAN BERNARDINO
Del Rosa
Patton
Harlem Springs
Highlands
East Highlands
COLTON
Bloomington
Crestmore
Wineville
Pedley
Norco
Highgrove
Loma Linda
REDLANDS
Mentone
RIVERSIDE
Arlington
Yucaipa
BEAUMONT


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT - STATE ENGINEER.
Rectangular Coordinates are indicated in margin for 20,000 yard squares, parallel and at right angles to the 121° Meridian (Army Grid System, Zone G; see U S C & G Survey Special Publication N° 59, Dept. of Commerce, 1919.)
Latitude and Longitude lines shown are on North American Datum To plat corresponding lines of U S Geological Survey Maps before 1924, scale approximatly 650 feet north and 380 feet east
Road net from map on same scale of Southern California Gas Company, revisions and additions by Santa Ana Investigation. Streams from U S Geological Survey, County Surveyors of San Bernardino & Riverside, Orange County Flood Control, City Water Dept of San Bernardino and surveys by the Investigation
LEGEND
Well
Hydrographic Contours (Elev above Sea)
Basin Boundary
Approximate Location of Sudden Changes in Elevation of Water Plane
Depression Contours
Artesian Area
Boundary of Valley Floor
Boundary of old Alluvium
CLAREMONT
POMONA
ONTARIO
CHINO
CORONA
LA HABRA
BREA
Olinda
Buena Park
FULLERTON
Cypress
Los Alamitos
PLACENTIA
Yorba Linda
Richfield
Yorba
Stanton
ANAHEIM
Olive
SEAL BEACH
Westminster
Garden Grove
Sunset Beach
ORANGE
El Modena
Wintersburg
SANTA ANA
TUSTIN
HUNTINGTON BEACH
NEWPORT BEACH
Irvine
PACIFIC OCEAN
LOS ANGELES
ORANGE
COUNTY LINE
SAN BERNARDINO
ORANGE
COUNTY LINE
RIVERSIDE
ORANGE
COUNTY LINE
Brea Canyon
Carbon Canyon
Santa Ana River
118°00'
117°50'
117°40'
117°30'

63685


MAP 8
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
SANTA ANA
INVESTIGATION
ELEVATION OF GROUND WATERS
IN RECENT GRAVELS
AUTUMN OF 1927
1928
UPLAND
Alta Loma
ONTARIO
Cucamonga
FONTANA
RIALTO
SAN BERNARDINO
Del Rosa
Patton
Highlands
East Highlands
Bloomington
Wineville
Crestmore
COLTON
Loma Linda
Pedley
Norco
Highgrove
RIVERSIDE
REDLANDS
Mentone
Arlington
Yucaipa
BEAUMONT



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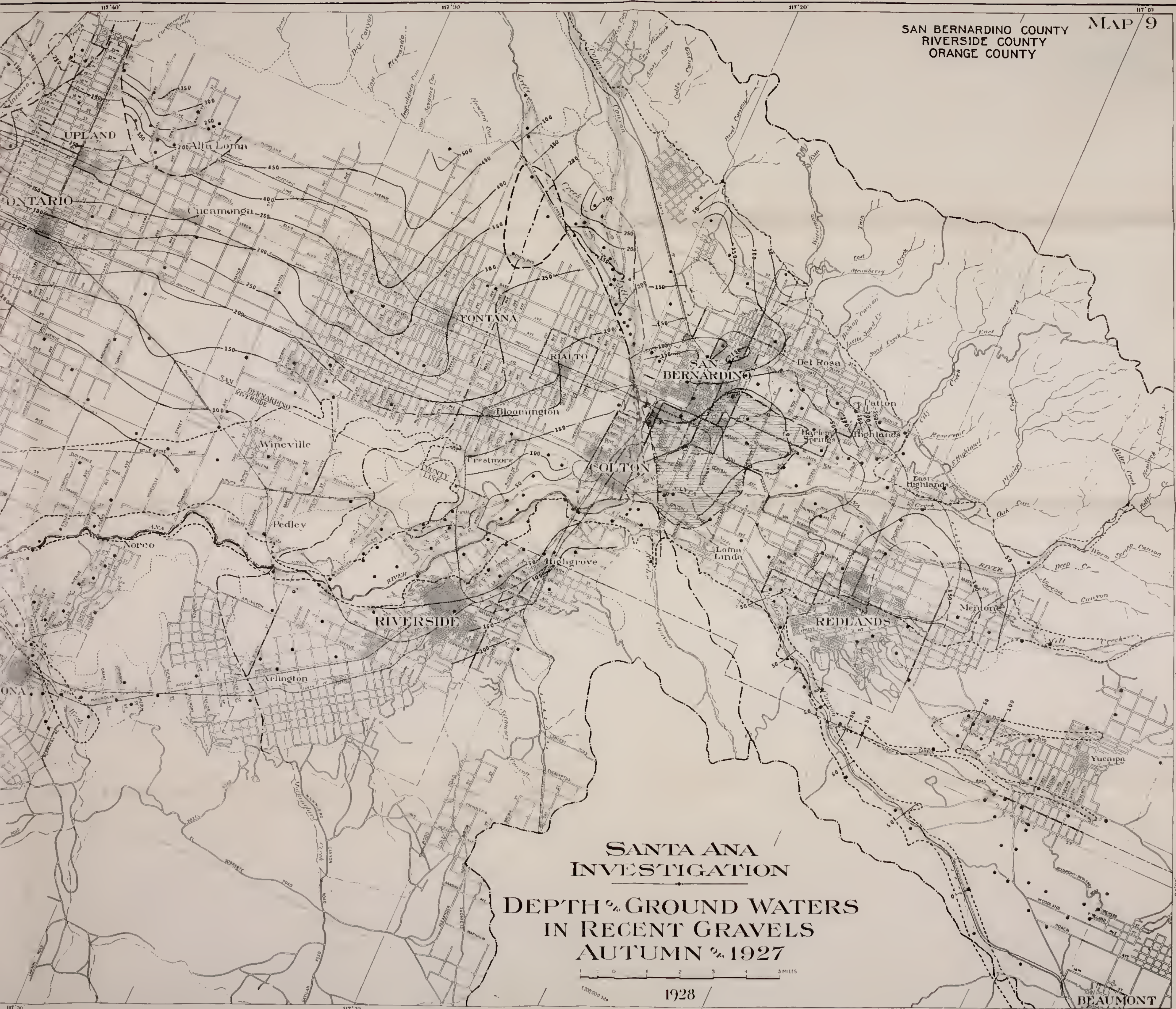
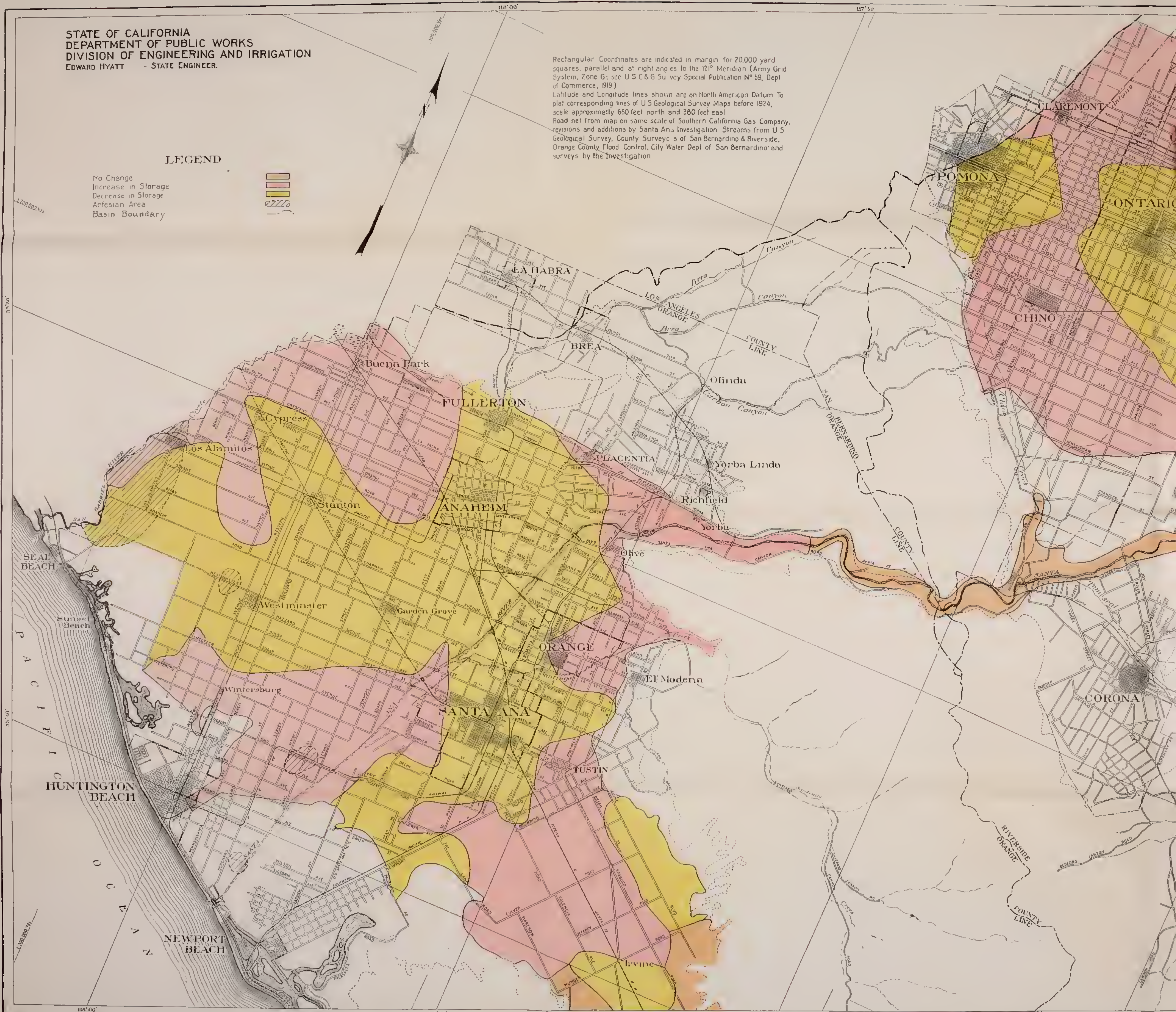
Rectangular Coordinates are indicated in margin for 20,000 yard squares, parallel and at right angles to the 121° Meridian (Army Grid System, Zone G; see U S C & G Survey Special Publication N° 59, Dept. of Commerce, 1919.)
Latitude and Longitude lines shown are on North American Datum To plat corresponding lines of U S Geological Survey Maps before 1924, scale approximately 650 feet north and 380 feet east
Road net from map on same scale of Southern California Gas Company, revisions and additions by Santa Ana Investigation. Streams from U S Geological Survey, County Surveyors of San Bernardino & Riverside, Orange County Flood Control, City Water Dept of San Bernardino and surveys by the Investigation.
LEGEND
Well
Hydrographic Contour
Basin Boundary
Approximate Location of Sudden Changes in Elevation of Water Plane
Boundary of Recent Alluvium (free Gravels)
Artesian Area
Boundary of Valley Floor
118°00'
117°50'
117°40'
117°30'
118°10'
LA HABRA
BREA
Buena Park
FULLERTON
Cypress
Los Alamitos
PLACENTIA
Yorba Linda
Olinda
Richfield
Yorba
Stanton
ANAHEIM
Olive
SEAL BEACH
Sunset Beach
Westminster
Garden Grove
ORANGE
El Modena
Wintersburg
SANTA ANA
TUSTIN
HUNTINGTON BEACH
NEWPORT BEACH
Irvine
PACIFIC OCEAN
POMONA
CLAREMONT
ONTARIO
CHINO
CORONA
LOS ANGELES ORANGE COUNTY LINE
SAN BERNARDINO ORANGE COUNTY LINE
RIVERSIDE ORANGE COUNTY LINE
Brea Canyon
Carbon Canyon

63685



MAP 9
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
UPLAND
Alta Loma
ONTARIO
Cucamonga
FONTANA
RIALTO
SAN BERNARDINO
Del Rosa
Patton
Harlem Springs
Highlands
East Highlands
Bloomington
Wineville
Crestmore
COLTON
Pedley
Norco
Highgrove
Loma Linda
RIVERSIDE
REDLANDS
Mentone
Arlington
Yucaipa
BEAUMONT
SANTA ANA INVESTIGATION
DEPTH OF GROUND WATERS IN RECENT GRAVELS AUTUMN OF 1927
1928


STATE OF CALIFORNIA
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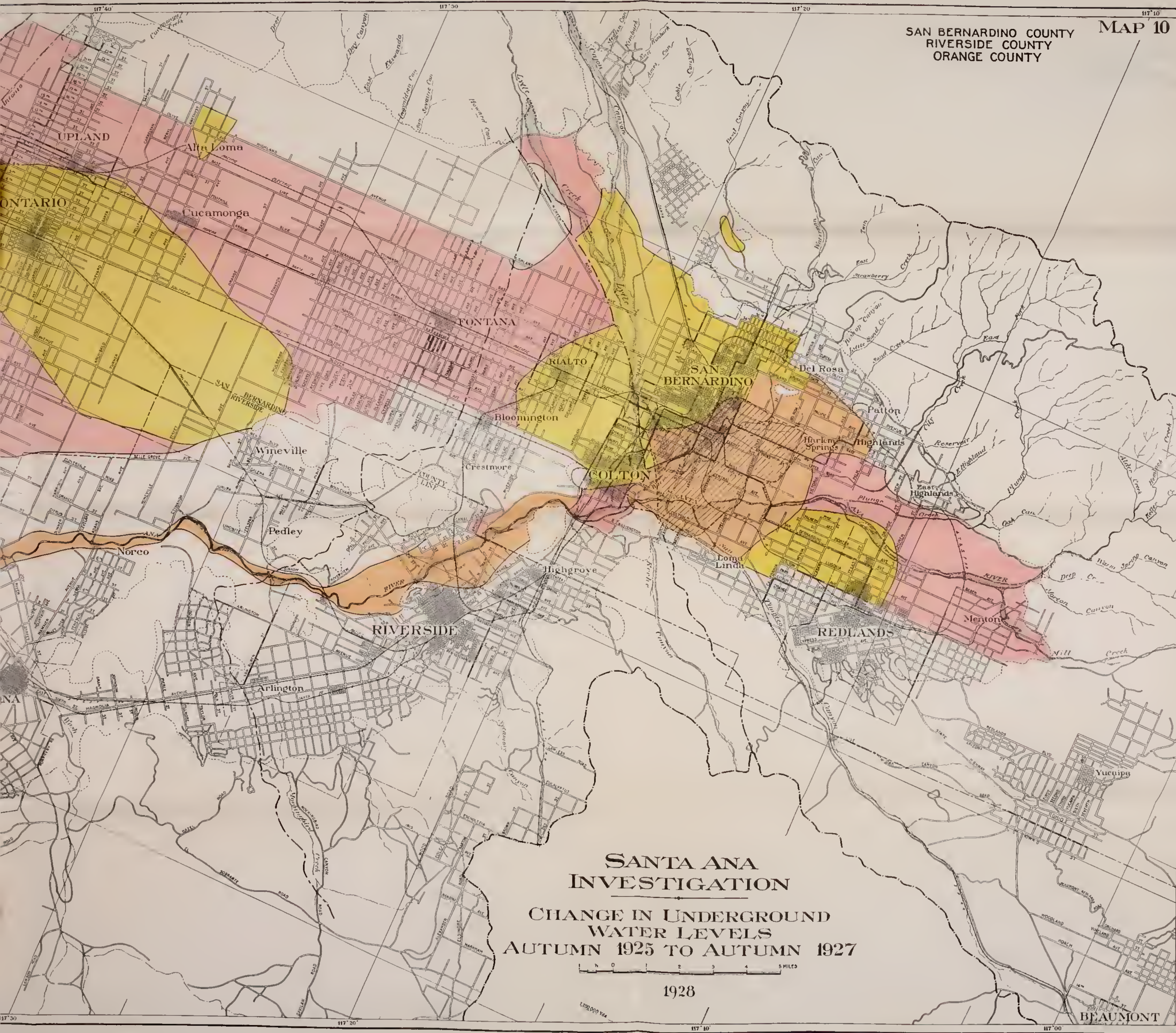
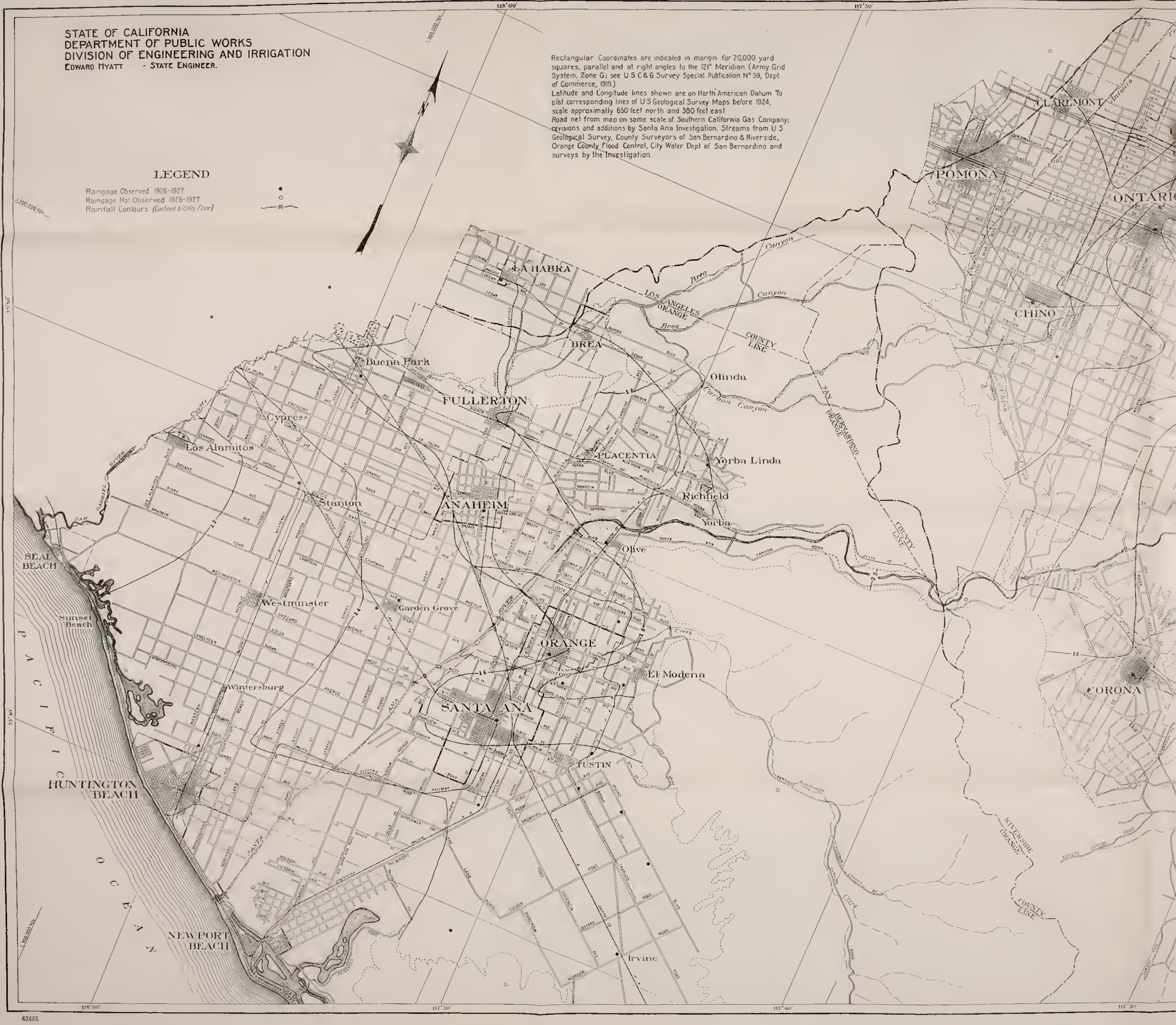
Rectangular Coordinates are indicated in margin for 20,000 yard squares, parallel and at right angles to the 121° Meridian (Army Grid System, Zone G; see U S C & G Survey Special Publication N° 59, Dept of Commerce, 1919)
Latitude and Longitude lines shown are on North American Datum To plat corresponding lines of U S Geological Survey Maps before 1924, scale approximatly 650 feet north and 380 feet east
Road net from map on same scale of Southern California Gas Company, revisions and additions by Santa Ana Investigation Streams from U S Geological Survey, County Surveyors of San Bernardino & Riverside, Orange County Flood Control, City Water Dept of San Bernardino and surveys by the Investigation
LEGEND
No Change
Increase in Storage
Decrease in Storage
Artesian Area
Basin Boundary
LA HABRA
BREA
Olinda
Yorba Linda
Richfield
Yorba
PLACENTIA
FULLERTON
Buena Park
Cypress
Los Alamitos
Stanton
ANAHEIM
Olive
Westminster
Garden Grove
ORANGE
El Modena
Wintersburg
SANTA ANA
TUSTIN
SEAL BEACH
Sunset Beach
HUNTINGTON BEACH
NEWPORT BEACH
Irvine
POMONA
CLAREMONT
ONTARIO
CHINO
CORONA
PACIFIC OCEAN
LOS ANGELES
ORANGE
COUNTY LINE
SAN BERNARDINO
ORANGE
RIVERSIDE
ORANGE
Brea Canyon
Carbon Canyon
118°00'
117°50'
117°40'
117°30'
63685


MAP 10
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
SANTA ANA INVESTIGATION
CHANGE IN UNDERGROUND WATER LEVELS
AUTUMN 1925 TO AUTUMN 1927
5 MILES
1928
UPLAND
Alta Loma
ONTARIO
Cucamonga
FONTANA
RIALTO
SAN BERNARDINO
Del Rosa
Patton
Highlands
Harlem Springs
East Highlands
Bloomington
Wineville
Crestmore
COUNTY LINE
COLTON
Pedley
Norco
Highgrove
Loma Linda
REDLANDS
Mentone
RIVERSIDE
Arlington
Yucaipa
BEAUMONT
SANTA ANA RIVER
Mill Creek
Plunge Creek
Lytle Creek
Cajon Canyon
Devil Canyon
Day Canyon
Deer Creek
117°40'
117°30'
117°20'
117°10'
117°00'
34°10'
34°00'



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Rectangular Coordinates are indicated in margin for 20,000 yard squares, parallel and at right angles to the 121° Meridian. (Army Grid System, Zone G; see U S C&G Survey Special Publication N° 59, Dept. of Commerce, 1919.)
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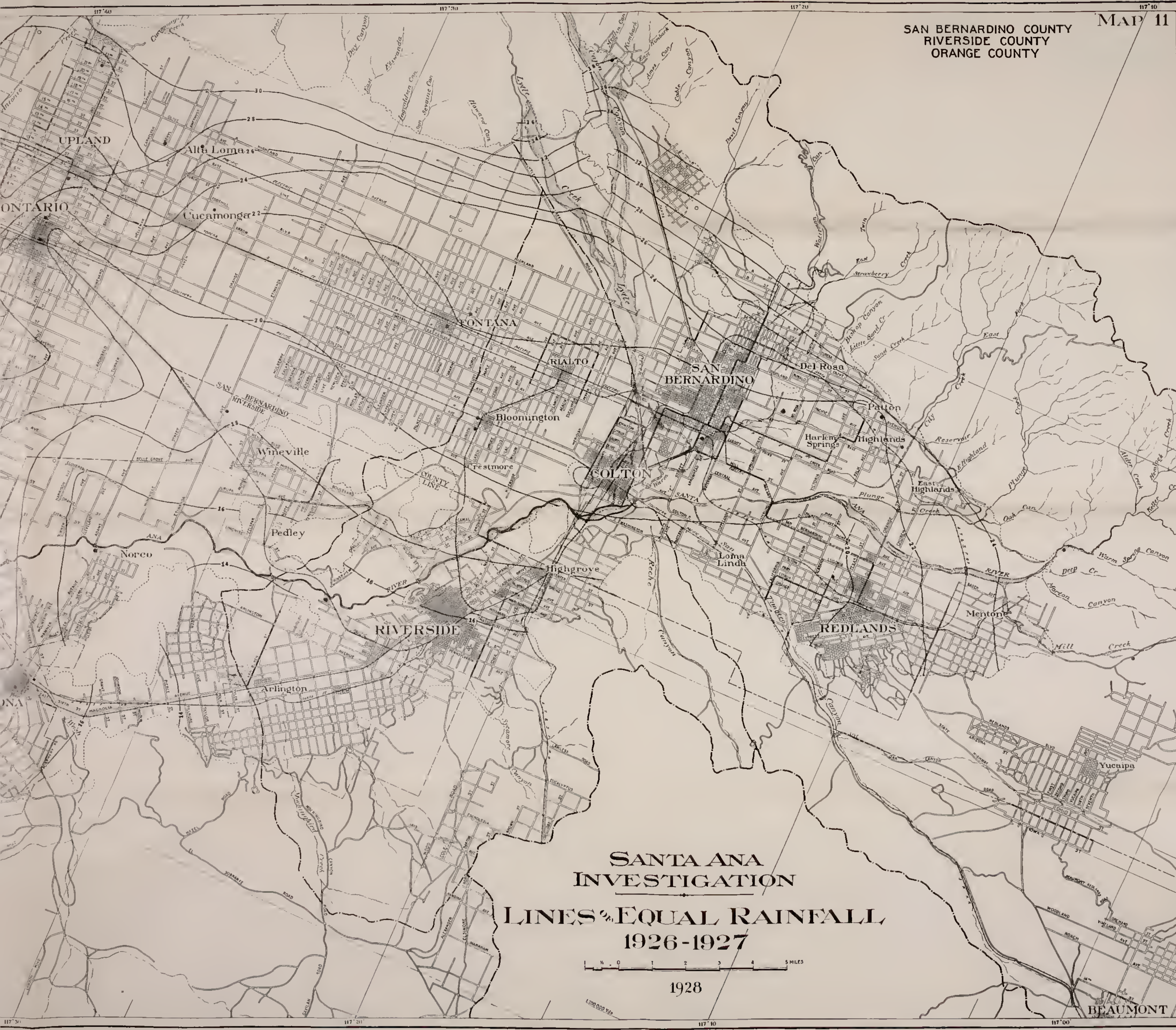
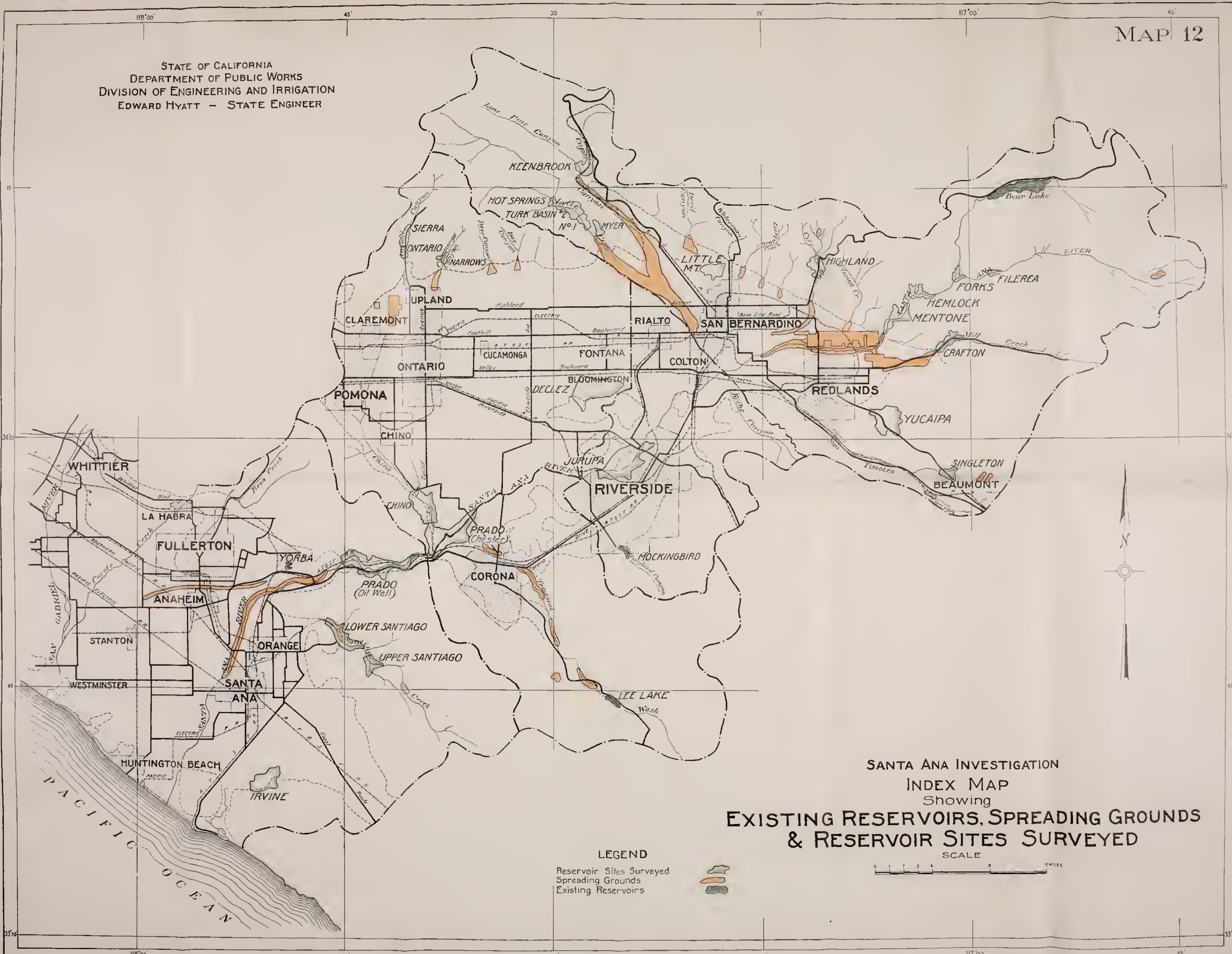
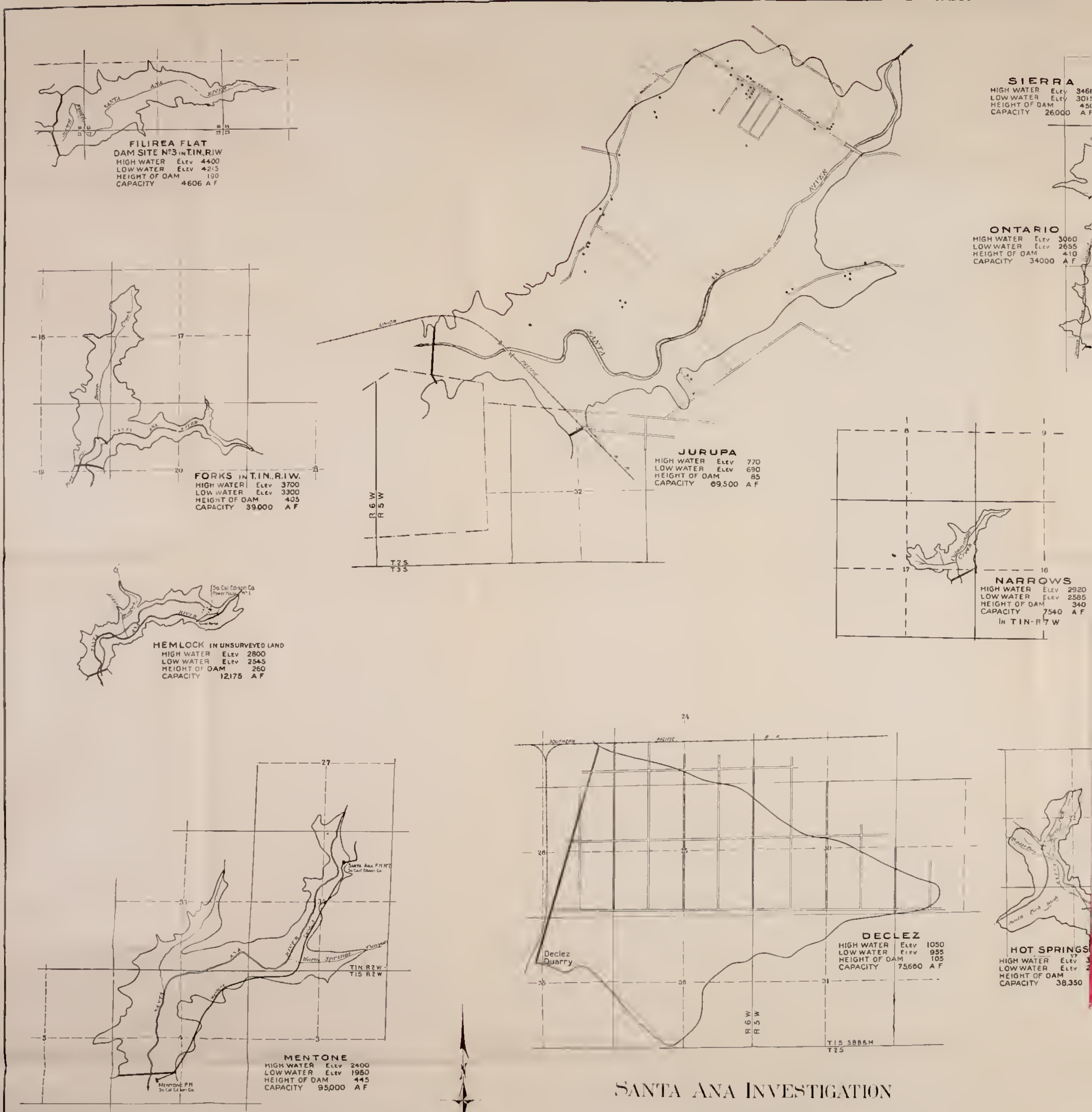
Road net from map on same scale of Southern California Gas Company; revisions and additions by Santa Ana Investigation. Streams from U S Geological Survey, County Surveyors of San Bernardino & Riverside, Orange County Flood Control, City Water Dept of San Bernardino and surveys by the Investigation.
LEGEND
Raingage Observed 1926-1927
Raingage Not Observed 1926-1927
Rainfall Contours (Confined to Valley Floor)
118°00'
117°50'
LA HABRA
BREA
Buena Park
FULLERTON
Cypress
Los Alamitos
PLACENTIA
Yorba Linda
Olinda
Richfield
Yorba
Stanton
ANAHEIM
Olive
Westminster
Garden Grove
ORANGE
El Modena
Wintersburg
SANTA ANA
TUSTIN
Irvine
SEAL BEACH
Sunset Beach
HUNTINGTON BEACH
NEWPORT BEACH
PACIFIC OCEAN
LOS ANGELES
ORANGE
COUNTY LINE
SAN BERNARDINO
ORANGE
RIVERSIDE
ORANGE
COUNTY LINE
CLAREMONT
POMONA
ONTARIO
CHINO
CORONA
Brea Canyon
Carbon Canyon
63685


MAP 11
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY
SANTA ANA INVESTIGATION
LINES OF EQUAL RAINFALL
1926-1927
1928
UPLAND
Alta Loma
ONTARIO
Cucamonga
FONTANA
RIALTO
SAN BERNARDINO
Del Rosa
Patton
Bloomington
Harlem Springs
Highlands
Wineville
Crestmore
COLTON
East Highlands
Pedley
Norco
Loma Linda
Highgrove
Mentone
RIVERSIDE
REDLANDS
Arlington
Yucaipa
BEAUMONT



MAP 12
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT — STATE ENGINEER
SANTA ANA INVESTIGATION
INDEX MAP
Showing
EXISTING RESERVOIRS, SPREADING GROUNDS
& RESERVOIR SITES SURVEYED
SCALE
LEGEND
Reservoir Sites Surveyed
Spreading Grounds
Existing Reservoirs
KEENBROOK
HOT SPRINGS
TURK BASIN
MYER
SIERRA
ONTARIO
NARROWS
LITTLE MT.
HIGHLAND
Bear Lake
FORKS
FILEREA
HEMLOCK
MENTONE
CRAFTON
UPLAND
CLAREMONT
RIALTO
SAN BERNARDINO
CUCAMONGA
FONTANA
COLTON
ONTARIO
BLOOMINGTON
POMONA
DECLEZ
REDLANDS
YUCAIPA
CHINO
SINGLETON
BEAUMONT
WHITTIER
JURUPA
RIVERSIDE
LA HABRA
CHINO
PRADO (Chester)
FULLERTON
YORBA
MOCKINGBIRD
CORONA
PRADO (Oil Well)
ANAHEIM
LOWER SANTIAGO
UPPER SANTIAGO
STANTON
ORANGE
WESTMINSTER
SANTA ANA
LEE LAKE
HUNTINGTON BEACH
IRVINE
PACIFIC OCEAN
SANTA ANA RIVER
SAN GABRIEL RIVER



SANTA ANA INVESTIGATION

SURVEYS OF
RESERVOIR SITES

For Sites in Lower Santa Ana Canyon See Sheet 2

SCALE

2000 1000 500 0 1/4 1/2 1 MILE

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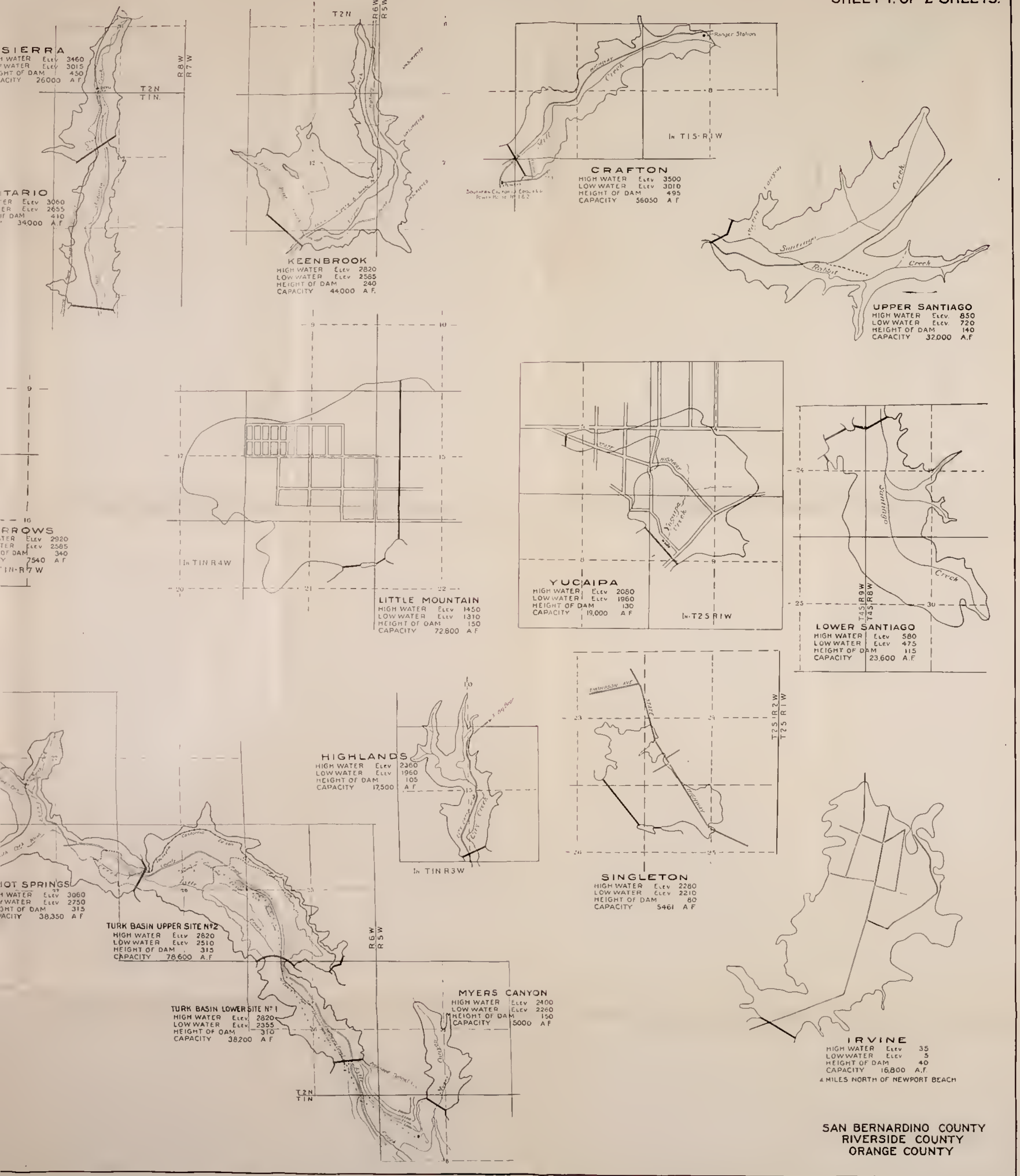
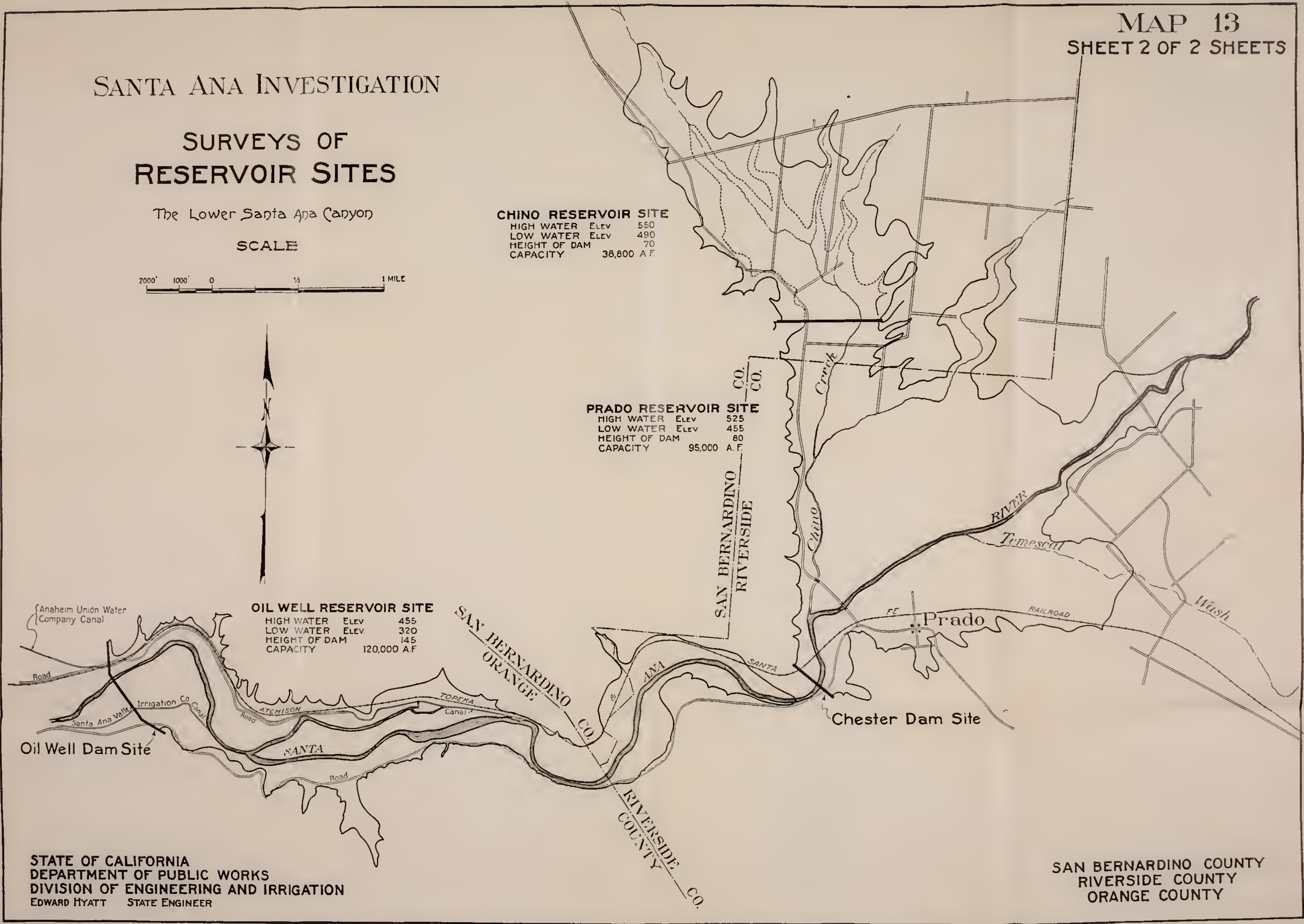
63015

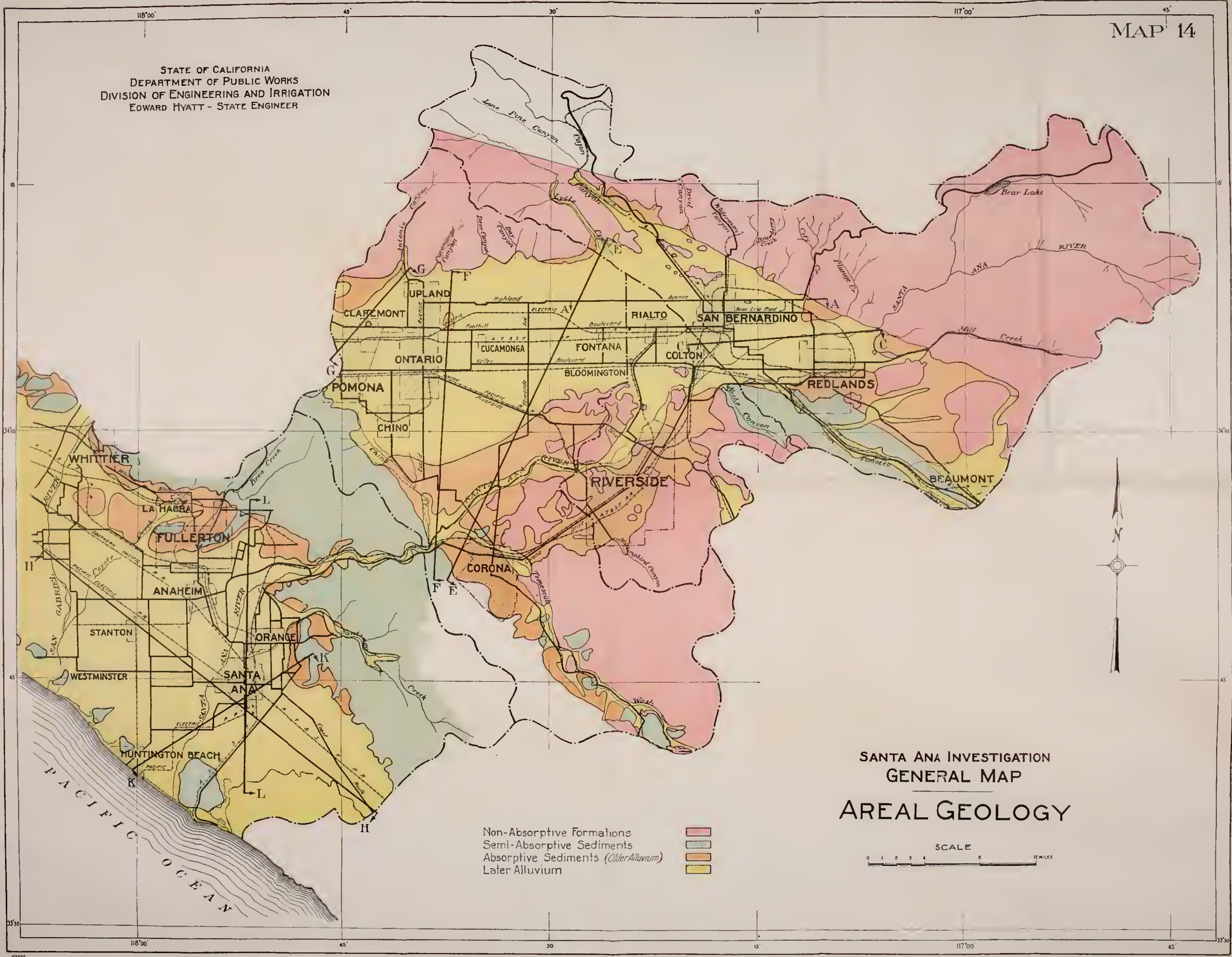
MAP 13
SHEET 1. OF 2 SHEETS.



SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY


MAP 13
SHEET 2 OF 2 SHEETS
SANTA ANA INVESTIGATION
SURVEYS OF
RESERVOIR SITES
The Lower Santa Ana Canyon
SCALE
2000' 1000' 0 ½ 1 MILE
CHINO RESERVOIR SITE
HIGH WATER ELEV 550
LOW WATER ELEV 490
HEIGHT OF DAM 70
CAPACITY 38,800 A.F.
PRADO RESERVOIR SITE
HIGH WATER ELEV 525
LOW WATER ELEV 455
HEIGHT OF DAM 80
CAPACITY 95,000 A.F.
OIL WELL RESERVOIR SITE
HIGH WATER ELEV 455
LOW WATER ELEV. 320
HEIGHT OF DAM 145
CAPACITY 120,000 A.F.
Anaheim Union Water Company Canal
Road
Santa Ana Valley Irrigation Co. Canal
Oil Well Dam Site
ATCHISON
TOPEKA
Canal
Road
SANTA
Road
SAN BERNARDINO CO.
ORANGE CO.
RIVERSIDE COUNTY
CO.
SAN BERNARDINO CO.
RIVERSIDE CO.
ANA
SANTA
Chester Dam Site
Chino
Creek
RIVER
Temescal
Wash
FE
RAILROAD
Prado
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT STATE ENGINEER
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
ORANGE COUNTY

63685


MAP 14
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
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EDWARD HYATT - STATE ENGINEER
SANTA ANA INVESTIGATION
GENERAL MAP
AREAL GEOLOGY
Non-Absorptive Formations
Semi-Absorptive Sediments
Absorptive Sediments (Older Alluvium)
Later Alluvium
SCALE
12 MILES
PACIFIC OCEAN
SAN BERNARDINO
RIVERSIDE
REDLANDS
BEAUMONT
COLTON
RIALTO
FONTANA
BLOOMINGTON
CUCAMONGA
ONTARIO
UPLAND
CLAREMONT
POMONA
CHINO
CORONA
WHITTIER
LA HABRA
FULLERTON
ANAHEIM
ORANGE
STANTON
WESTMINSTER
SANTA ANA
HUNTINGTON BEACH
Bear Lake
SANTA ANA RIVER
Mill Creek
Lone Pine Canyon
Cajon Canyon
Lytle Creek
San Antonio Canyon
Cucamonga Canyon
Deer Canyon
Day Canyon
Devil Canyon
Waterman Canyon
Strawberry Creek
City Creek
Plunge Cr
San Timoteo Canyon
Reche Canyon
Brea Creek
Chino Creek
Santiago Creek
Temescal Wash
Coyote Creek
SAN GABRIEL RIVER
118°00'
117°00'
34°00'
33°30'